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TECHNICAL MEMORANDUM

Supplemental Ecological Risk Assessment for the East Helena Smelter Site, Montana

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1 INTRODUCTION

1.1 Purpose

This technical memorandum presents a supplemental ecological risk evaluation for aquatic and terrestrial receptors at the East Helena Smelter Superfund site located in Lewis and Clark County, Montana. The purpose of this document is to address exposure areas, receptors and pathways that were not evaluated as part of the original 1989 Comprehensive Endangerment Assessment (CEA) (Hunter/ESE, 1989). The problem formulation in Section 4 provides a detailed discussion of which exposure areas, receptors and pathways were evaluated as part of the current assessment.

This assessment will identify the potential for adverse effects (risks) to ecological receptors due to exposures from contaminants released to the environment during historical activities at the East Helena Smelter site. This information, along with other relevant site information, will be used by risk managers to decide whether remedial actions are needed to protect ecological receptors from site-related releases.

1.2 Document Organization

In addition to this introduction section, this document is organized into the following sections:

Section 2 – Site Characterization. This section details the location, history, and environmental setting of the East Helena Site.

Section 3 – Data Summary. This section summarizes the available data for the site, identifies the data gaps for ecological risk assessment, and presents the most current data used to perform the risk assessment.

Section 4 – Problem Formulation. This section presents the ecological problem formulation, including a summary of the CEA findings and conclusions, the site conceptual model, and a description of the basic methods used in the assessment.

Section 5 – Risk Assessment for Aquatic Receptors. This section presents the ecological risk assessment for the aquatic receptors of potential concern at the East Helena Site.

Section 6 – Risk Assessment for Wildlife Receptors. This section presents the ecological risk assessment for wildlife receptors (birds and mammals) of potential concern at the East Helena Site.

Section 7 – Uncertainties. This section provides a summary of the main uncertainties that limit confidence in the risk characterization for each of the exposure areas and classes of ecological receptors evaluated at the site.

Section 8 – References. This section provides citations for all data, methods, studies, and reports utilized in the ecological risk assessment.

2 SITE CHARACTERIZATION

The Remedial Investigation report (CH2MHill, 1987) and the US Environmental Protection Agency (USEPA) Region 8 Superfund Program website (USEPA, 2003a) provide a detailed description of the site along with a summary of the site history and background. Pertinent information is summarized briefly below.

2.1 Site Location and History

The East Helena Superfund site is located in west-central Montana, three miles east of Helena (Figure 2-1). The site encompasses approximately 140 acres and centers around a smelting facility owned by the American Smelting and Refining Company (ASARCO). The site also includes the nearby town of East Helena and surrounding rural agricultural lands in the Helena Valley.

Figure 2-2 provides a map of the smelter site. Lead and zinc smelting activities began at the smelter in 1888, and operations continued until April 2001. By-products of these smelting operations included sulfuric acid, matte (iron, copper and lead oxides), and speiss (copper arsenides and antimonides) (USFWS, 1997). Site operations resulted in releases of smelter-related contaminants into the surrounding environment, causing increased concentrations of metals in soil, sediment, surface water and groundwater of the Helena Valley.

The East Helena site was placed on the USEPA National Priorities List (NPL) in September 1984. Since its listing, there have been several site investigations conducted to characterize the nature and extent of site-related metals contamination and to evaluate potential risks to humans and the environment. As a result of these investigations, soils at many homes in East Helena and along the Wilson Irrigation Ditch have been remediated. In the fall of 1996, contaminated on-site soils and pond sediments from the Lower Lake, a site processing pond, were removed and stored in an on-site landfill.

2.2 Environmental Setting

The area on and around the site includes both aquatic and terrestrial habitat where ecological receptors could be exposed to site-related contaminants.

2.2.1 Aquatic Habitat

On-site aquatic habitat areas include the Lower Lake, the Upper Lake, and the marsh areas south and east of the Upper Lake (Figure 2-2). Off-site aquatic habitat areas include Prickly Pear Creek, which flows in a northerly direction along the eastern site boundary (Figure 2-2). For the purposes of this risk assessment, an evaluation of potential risks from Prickly Pear Creek was limited to areas that are upstream of Lake Helena. This assessment does not include an evaluation of potential risks to ecological receptors from exposures at Lake Helena. The aquatic habitat areas that were evaluated as part of this assessment are discussed in more detail below.

Lower Lake

The Lower Lake was used historically as a site processing pond. Groundwater data provided in the CEA suggested that a plume of metal contamination originating from Lower Lake may have influenced surface water quality in Prickly Pear Creek (Hunter/ESE, 1989). As part of remediation efforts conducted in the fall of 1996, sediments from Lower Lake were dredged and placed in an on-site landfill.

Upper Lake and Marsh Area

The Upper Lake and marsh area are located south of the Lower Lake and smelter facility. This area is divided into approximately one-third open water and two-thirds cattail marsh (USEPA, 2004). The open water portion is relatively shallow (5 to 12 feet deep), while the marsh depth ranges from a few inches to two feet. The sediments in the marsh area are mainly anaerobic (USEPA, 2004). Historically, an ore storage area was located along the northeast boundary of the Upper Lake (see Figure 2-2).

Prickly Pear Creek

Prickly Pear Creek flows along the eastern boundary of the site. It is one of the main streams in the Helena Valley and flows in a northwesterly direction to its confluence with Ten Mile Creek, one mile southwest of Lake Helena (Hunter/ESE, 1989). Previous investigations have reported elevated concentrations of arsenic and other metals in Prickly Pear Creek sediments (USFWS, 1997). Historically, Prickly Pear Creek may have been influenced by seepage from Lower Lake. The on-site slag pile (see Figure 2-2) may act as a source of metals for the creek sediments (USFWS, 1997). Conditions in Prickly Pear Creek upstream of the East Helena site may be influenced by historical mining operations and should not be interpreted as an unimpacted "pristine" background.

2.2.2 Terrestrial Habitat

Terrestrial habitat areas include both on-site locations near buildings and stockpile areas as well as off-site upland areas in the surrounding Helena valley that may have been impacted by smelter emissions.

3 DATA SUMMARY

3.1 Historic Investigations

There are four reports which provide much of the historical environmental data for the East Helena Smelter site. These reports are:

- CH2MHill (1987) – Remedial Investigation (RI) of Soils, Vegetation, and Livestock;
- Hunter/ESE (1989) – Comprehensive Endangerment Assessment (CEA);
- USFWS (1997) – Biological Indices of Lead Exposure in Relation to Heavy Metal Residues in Sediment and Biota from Prickly Pear Creek and Lake Helena, Montana; and
- USGS (1998) – Field Screening of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Helena Valley, West-Central Montana, 1995.

Table 3-1 provides a summary of the types of data collected as part of each one of these investigations.

3.2 Identified Data Gaps for Ecological Risk Assessment

Potential risks to ecological receptors were first evaluated as part of the CEA (Hunter/ESE, 1989). The CEA evaluated risks to aquatic receptors from direct contact with surface water, terrestrial plants from direct contact with surface soils, and livestock from ingestion surface water, soil and plants and inhalation. The primary contaminants of concern evaluated in the CEA were arsenic, cadmium, copper, iron, lead, manganese, and zinc.

The aquatic receptor assessment in the CEA focused only on exposures to surface water in Prickly Pear Creek, and did not evaluate potential exposures in the on-site lakes and marsh area (see Figure 2-2). The aquatic assessment also did not include an evaluation of potential risks to benthic invertebrates from direct contact with sediments. The terrestrial plant assessment in the CEA was based on a soil database compiled from an extensive sampling effort both on-site and throughout the Helena Valley conducted as part of the RI in 1987. Although the CEA evaluated risks to livestock (which are representative of large mammalian herbivore exposures) from several exposure pathways in upland areas, it did not include an assessment of potential risks to birds and small mammalian wildlife.

3.3 2003 Ecological Field Investigation

As seen in Table 3-1, the RI report provided measured data for soils and plant tissues from on-site locations and throughout the Helena Valley. However, there are limited data on the aquatic habitat and exposure levels for the on-site lakes and marsh area and Prickly Pear Creek near the site. Therefore, a supplemental ecological field investigation was performed in the fall of 2003 to address these data gaps. This field investigation was conducted to gather additional information on the environmental habitat and contaminant concentrations in the on-site lakes and marsh area and in Prickly Pear Creek under current settings. The sampling details of the 2003 ecological field investigation are provided in the Sampling and Analysis Plan and Quality Assurance Project Plan (SAP/QAPP) (USEPA, 2003b).

In brief, this field investigation focused on the Lower Lake, the Upper Lake and marsh areas, and Prickly Pear Creek. Samples collected and analyzed for metals included surface water, bulk sediment, sediment porewater, aquatic plants, aquatic invertebrates, and fish. Sediment toxicity tests were conducted using sediments from the on-site lakes and marsh area using *Hyalella azteca*. In addition, the benthic macroinvertebrate community was evaluated at several locations using the Rapid Bioassessment Protocol (RBP) methodology (Barbour et al., 1999). Several ponds located along the edge of Canyon Ferry Reservoir were selected to serve as reference locations for the on-site ponds. For Prickly Pear Creek, a sampling station located upstream of the site served as a reference location. It is important to note that conditions at this upstream location may be influenced by historical mining activities and should not be interpreted as a "pristine" background location. However, comparisons of upstream to downstream provide information on the contribution of the East Helena site to the stream condition.

Figure 3-1 Part A (on-site lakes and Prickly Pear Creek locations) and Part B (Canyon Ferry Reservoir reference locations) show the stations that were sampled as part of the 2003 ecological field investigation. Table 3-2 summarizes the types of samples collected from each station. Appendix A provides detailed analytical results for all the environmental samples collected during this investigation.

4 PROBLEM FORMULATION

4.1 Site Conceptual Model

Figure 4-1 presents a site conceptual model for exposure of ecological receptors at the East Helena Smelter Site. As seen, ecological receptors that may be exposed include aquatic receptors (fish and aquatic invertebrates), terrestrial receptors (plants and soil invertebrates), wildlife receptors (birds and mammals), and livestock. Each receptor class may be exposed to chemical contamination via contact with one or more environmental media, including surface water, sediment, soil, and aquatic or terrestrial food items. However, not all of these exposure pathways are likely to be of equal concern. For the purposes of this risk evaluation, each exposure pathway was classified as follows:

- The pathway is considered to be of potential concern, and sufficient data exist to support a quantitative or semi-quantitative risk evaluation. These cases are indicated by boxes containing a solid circle (●). These pathways are the primary focus of this risk assessment.
- The pathway is considered to be of potential concern, but available data are too limited to support a reliable quantitative risk evaluation. These cases are shown by boxes with an open circle (○) and are discussed qualitatively in the uncertainties section.
- The risk posed by the pathway is likely to be minor, either on an absolute basis and/or in comparison to other exposure pathways that affect the same receptor. These cases are indicated by boxes with an "X".
- The pathway is considered to be incomplete (i.e., not thought to occur). These cases are shown as open boxes.

The following sections provide a more complete discussion of which pathways have been selected for quantitative evaluation.

4.2 Exposure Pathway Screening

4.2.1 Fish

The primary exposure pathway for fish is direct contact with surface water. Although the CEA did evaluate this exposure pathway, the exposure area was restricted to Prickly Pear Creek and did not include an evaluation of potential risks in the on-site lakes and marsh area. Because there are new surface water data available for these potential exposure areas, this pathway was evaluated quantitatively in this assessment. Fish may also be exposed by direct contact with sediment, but this is likely to be a minor source of exposure compared to surface water, so this pathway was not quantified. Although toxicity data for oral exposures in fish are quite limited, exposures via ingestion of food items and sediment were evaluated quantitatively for a subset of metals (arsenic, cadmium, copper, lead, and zinc).

4.2.2 Benthic Invertebrates

For benthic invertebrates, direct contact with both surface water and sediment are likely to be important exposure pathways. As noted above, the CEA did evaluate potential risks to aquatic receptors from surface water, but the evaluation focused only on Prickly Pear Creek. Because there are new surface water data available for exposure areas not previously evaluated, this pathway was evaluated quantitatively in this assessment. The CEA did not include an evaluation of potential risks to benthic organisms from direct contact with sediment in any exposure area, so this pathway was also evaluated quantitatively in this assessment. Benthic invertebrates are also likely to be exposed via ingestion of sediment or contaminated prey, but no oral toxicity data are available for benthic organisms. However, sediment toxicity values for benthic invertebrates probably include at least some contribution from ingestion exposures (assuming the organisms continue to feed during the study), so this pathway was not evaluated separately.

4.2.3 Plants and Soil Invertebrates

The primary exposure pathway for both terrestrial plants and soil invertebrates is direct contact with contaminated soils. For terrestrial plants exposure may also occur due to deposition of dust on leaf surfaces, but this pathway is generally believed to be small compared to root exposures.

The potential risk to terrestrial plants from direct contact with metals in surface soil was evaluated previously as part of the CEA (Hunter/ESE, 1989). In brief, the CEA concluded that although maximum concentrations exceeded tolerable levels for plants, the reported levels in soil were not sufficiently high to expect that metals in soil would result in widespread damage to plants (Hunter/ESE, 1989). Because no new data have been collected to provide a basis for an improved assessment of risks to plants, no additional evaluation of risks to plants is provided in this risk assessment.

Although the CEA did not evaluate risks to soil invertebrates, toxicity values for soil invertebrates are generally similar to or higher than toxicity values for plants. This is illustrated in Table 4-1, which provides a summary of available soil toxicity benchmarks for terrestrial plants and soil organisms derived as part of the Ecological Soil Screening Level (Eco-SSL) effort (USEPA, 2003c) and the from the Oak Ridge National Laboratory (ORNL) (Efroymson, 1997a,b). Potential risks to soil invertebrates are likely to be similar to or less than those estimated for terrestrial plants previously in the CEA. Therefore, this assessment does not evaluate risks to soil invertebrates.

4.2.4 Wildlife Receptors (Birds and Mammals)

Wildlife (birds and mammals) may be exposed via several ingestion pathways, including ingestion of surface water, sediment, soil, and dietary items. While direct contact (i.e., dermal exposure) of birds and mammals to soils, sediments, and surface water and inhalation exposure to airborne dusts may occur, these exposures are judged to be minor in comparison to exposures from ingestion (USEPA, 2003c). Exposure to soil and terrestrial dietary items can occur in the upland areas off-site. Ingestion of surface water, sediment, and aquatic food items may occur in the riparian areas along Prickly Pear Creek and at the on-site lakes and marsh area. The CEA did not evaluate potential risks to birds and small mammals for any of these exposure areas, therefore each of these pathways were evaluated quantitatively in this assessment.

4.2.5 Livestock

Risks to livestock were evaluated as part of the CEA (Hunter/ESE, 1989). In brief, the CEA evaluated risks from ingestion of soil and plants, dermal contact with surface water, and inhalation of dust. In addition, the CEA assessed livestock exposure based on measured tissue levels in cattle from the Helena Valley. Based on these evaluations, the CEA concluded that although exposures in livestock were elevated, they were not high enough to cause adverse effects. Because no new data have been collected to refine the exposure assessment for livestock, a re-evaluation of potential risks to livestock was not performed as part of this assessment.

4.3 Ecological Risk Assessment Approach

Assessment endpoints are the characteristics of the ecological system that are to be protected in order to achieve management goals. Assessment endpoints are either measured directly or are evaluated through indirect measures. Measurement endpoints represent quantifiable ecological characteristics that can be measured, interpreted, and related to the valued ecological components chosen as the assessment endpoints (USEPA, 1992; 1997). Measurement endpoints can be divided into three basic categories, as follows:

- Hazard Quotients (HQs)
- Site-specific toxicity tests
- Observations of population and community demographics

These three basic types of measurement endpoint are described in more detail below.

4.3.1 Hazard Quotients

A Hazard Quotient (HQ) is the ratio of the estimated exposure of a receptor at the site to a "benchmark" exposure that is believed to be without significant risk of unacceptable adverse effect:

HQ = Exposure / Benchmark

Exposure concentration values in environmental media such as soil, sediment and water are usually measured directly, while concentrations in dietary items and tissues of exposed receptors may be measured directly or predicted using mathematical uptake models. In all cases, the benchmark toxicity value must be of the same type (concentration, dose) as the exposure estimate.

When a receptor is exposed by more than one pathway (e.g., birds and mammals), HQs for each exposure pathway are added across pathways resulting in a "Total HQ" for each chemical. In accordance with USEPA guidance, HQs for different chemicals are not added unless reliable data are available to indicate that the two (or more) chemicals act on the same target tissue by the same mode of action. At this site, HQ values for each chemical were not added across different chemicals.

If the value of an HQ is less than or equal to 1, risk of unacceptable adverse effects in the exposed individual is judged to be acceptable. If the HQ exceeds 1, the risk of an adverse effect in the exposed individual is of potential concern, with the probability and/or severity of effect tending to increase as the value of the HQ increases.

When interpreting HQ results for ecological receptors, it is important to remember that the assessment endpoint is usually based on the sustainability of exposed populations, and risks to some individuals in a population may be acceptable if the population is expected to remain healthy and stable. In these cases, population risk is best characterized by quantifying the fraction of all individuals that have HQ values greater than 1, and by the magnitude of the exceedences.

The fraction of the population that must have HQ values below a value of 1 in order for the population to remain stable depends on toxicological endpoint underlying the toxicity benchmark and the population dynamics of the exposed species (e.g., population size, birth/death rates, immigration/emigration rates). Because this type of detailed knowledge of population dynamics is generally not available on a site-specific basis, extrapolation from a distribution of individual risks to a characterization of population-level risks is generally uncertain. However, if all or nearly all of the HQs for individuals in a population of receptors are below 1, it is very unlikely that unacceptable population-level effects will occur in the exposed population. Conversely, if many or all of the individual receptors have HQs that are above 1, then unacceptable effects on the exposed population are more likely, especially if the HQ values are large. If only a small portion of the exposed population has HQ values that exceed 1, some individuals may be impacted, but population-level effects are not likely to occur. As the fraction of the population with HQ values above 1 increases, and as the magnitude of the exceedences increases, risk that a population-level effect will occur also increases. This concept is illustrated schematically in Figure 4-2.

In practice, estimating the distribution of HQ values in different individuals in a population is not always easy. Variability in the HQ for different members of a population can arise from one or both of two sources, depending on the size of the exposure area being assessed and the size of the home range of the receptor of concern. In cases where the home range is as large as the exposure area, and assuming the receptors tend to be exposed at random across the exposure area, exposure is related to the mean concentration across the exposure area (this is a constant, not a variable), and variation in exposure is related mainly to differences in the intake rates (dietary fractions) of different environmental media. For receptors that have a small home range compared to the size of the exposure area, the population consists of individuals residing at a number of different home ranges within the exposure area, and variability in the mean concentration of contaminant across different home ranges is usually the primary reason for between-individual variation in exposure.

Based on this, variability in exposure among individuals with small home ranges (this includes many small mammals and birds, benthic macroinvertebrates, and many fish) can be approximated by the variability in concentration values at different locations in the exposure area. It is important to note that this is only an approximation, since population density is often not uniform across an exposure area, depending on a number of key habitat variables. Thus, if 20% of all sampling locations in an exposure area yielded an HQ above 1, it is reasonable to estimate that about 20% of the population of small home range receptors could be at risk, but the actual fraction could be either lower or higher, depending on variability in habitat suitability.

Additional information that is sometimes useful in interpreting HQ values can be gathered by calculating HQs for reference areas. In cases where the HQ value for a reference area is higher than 1, some caution should be used in interpreting the results, since risks are usually not expected to be elevated in reference areas. In such cases, one possibility is that exposure and/or toxicity are overestimated, resulting in an overestimation of the HQ. However, it is important to recognize that an HQ above 1 in a reference area may occur as the result of contamination from other (non-site) sources, or, in the case of metals, from naturally occurring levels in the environment.

In interpreting HQ values and distributions of HQ values, it is always important to bear in mind that the values are predictions, and are subject to the uncertainties that are inherent in both the estimates of exposure and the estimates of toxicity benchmarks. Therefore, HQ values should be interpreted as estimates rather than highly precise values, and should be viewed as part of the weight of evidence along with the results of site-specific toxicity testing and direct observations on the structure and function of the receptor community (see below).

4.3.2 Site-Specific Toxicity Tests

Site-specific toxicity tests measure the response of receptors that are exposed to site media. This may be done either in the field or in the laboratory using media collected on the site. The chief advantage of this approach is that site-specific conditions which can influence toxicity are usually accounted for. A potential disadvantage is that, if toxic effects are observed to occur when test organisms are exposed to a site medium, it is usually not possible to specify which chemical or combination of chemicals is responsible for the effect. Rather, the results of the toxicity testing reflect the combined effect of the mixture of chemicals present in the site medium. In addition, it is often difficult to test the full range of environmental conditions which may occur at the site across time and space, either in the field or in the laboratory, so these studies are not always adequate to identify the boundary between exposures that are acceptable and those that are not.

4.3.3 Population and Community Demographic Observations

A third approach for evaluating impacts of environmental contamination on ecological receptors is to make direct observations on the receptors in the field, seeking to determine whether any receptor population has unusual numbers of individuals (either lower or higher than expected), or whether the diversity (number of different species) of a particular category of receptors (e.g., plants, benthic organisms, small mammals, birds) is different than expected. The chief advantage of this approach is that direct observation of community status does not require making the numerous assumptions and estimates needed in the HQ approach. However, there are also a number of important limitations to this approach. The most important of these is that both the abundance and diversity of an ecological population depend on many site-specific factors (habitat suitability, availability of food, predator pressure, natural population cycles, meteorological conditions, etc.), and it is often difficult to know what the expected (non-impacted) abundance and diversity of an ecological population should be in a particular area. This problem is generally approached by seeking an appropriate "reference area" (either the site itself before the impact occurred, or some similar site that has not been impacted), and comparing the observed abundance and diversity in the reference area to that for the site. However, it is sometimes quite difficult to locate reference areas that are truly a good match for all of the important habitat variables at the site, so comparisons based on this approach do not always establish firm cause-and-effect conclusions regarding the impact of environmental contamination on a receptor population.

4.3.4 Weight of Evidence Evaluation

As noted above, each of the measurement endpoints has advantages but also has limitations. For this reason, conclusions based on only one method of evaluation may be misleading. Therefore, the best approach for deriving reliable conclusions is to combine the findings across all of the methods for which data are available, taking the relative strengths and weaknesses of each method into account. If the methods all yield similar conclusions, confidence in the conclusion is greatly increased. If different methods yield different conclusions, then a careful review must be performed to identify the basis of the discrepancy, and to decide which approach provides the most reliable information.

5 RISK ASSESSMENT FOR AQUATIC RECEPTORS

As noted in the site conceptual model, fish and benthic invertebrates may be exposed to site-related contaminants through several potential pathways. The following exposure pathways were selected for quantitative evaluation.

- Direct contact of aquatic receptors with chemicals dissolved or suspended in surface water. This pathway is applicable to both fish and benthic invertebrates.
- Direct contact of benthic organisms with chemicals in sediment that have dissolved into the interstitial water (porewater) occupying the spaces between sediment particles. This pathway is most applicable to benthic invertebrate species that live buried within the sediment substrate.
- Ingestion of aquatic food items and sediment by fish. As noted previously, toxicity data for oral exposures in fish are quite limited and a quantitative evaluation was performed for only a subset of metals (arsenic, cadmium, copper, lead, and zinc).

Each of these exposure pathways were evaluated for three aquatic receptors exposure areas, including the Lower Lake, the Upper Lake and marsh area, and Prickly Pear Creek.

5.1 HQ Approach for Direct Contact of Aquatic Receptors with Surface Water

The risk evaluation for aquatic receptors from surface water was based on an HQ approach. An HQ is the ratio of the estimated exposure of a receptor to a toxicity benchmark (an exposure that is believed to be without significant risk of unacceptable adverse effect). For the evaluation of risks to aquatic receptors from direct contact with chemicals in surface water the HQ was calculated as:

$$HQ = Conc_{SW} / TB_{SW}$$

where:

$Conc_{SW}$ = chemical concentration in surface water (ug/L)
TB_{SW} = chemical toxicity benchmark for surface water (ug/L)

If the value of an HQ is less than or equal to one, risk of unacceptable adverse effects in the exposed organisms is judged to be acceptable. If the HQ exceeds one, the risk of adverse effect in the exposed organisms may be of potential concern.

5.1.1 Exposure Assessment

For inorganics, concentration values in surface water may be expressed either as total recoverable or as "dissolved" (that which passes through a fine-pore filter). There is general consensus that toxicity to aquatic receptors is dominated by the level of dissolved chemicals

(Prothro, 1993), since chemicals that are adsorbed onto particulate matter may be less toxic than the dissolved forms. Therefore, aquatic receptor exposures to inorganics in surface water were evaluated using dissolved concentrations.

Because concentrations of chemicals in surface water can vary significantly over time and location, exposure of aquatic receptors is best characterized as a distribution of individual values at each sampling location, rather than as an average of values over time and/or over locations.

For the purposes of this evaluation, surface water data were restricted to those samples collected during 2003 ecological field investigation in order to assess potential risks based on current site conditions. Surface water samples were collected from each sampling station (Figure 3-1). Because there were limited surface water data from each sampling station (only one sample per station), risks were calculated for each sample for each chemical at a location.

5.1.2 Toxicity Assessment

Toxicity benchmark values for the protection of aquatic life from direct contact with chemicals in surface water are available from several sources. Each of the sources evaluated in deriving surface water toxicity benchmarks is described briefly in Appendix B. This appendix also describes the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available.

Two different types of aquatic toxicity benchmark were selected – acute and chronic. The acute toxicity benchmark is intended to protect against short-term (48-96 hour) lethality, while the chronic toxicity benchmark is intended to protect against long-term effects on growth, reproduction, and survival. Because water hardness can affect toxicity for some metals (increasing hardness tends to decrease toxicity), hardness-dependant benchmarks were calculated based on the calculated hardness[1] for each exposure location.

The acute and chronic toxicity benchmark values for all chemicals analyzed in surface water are shown in Table 5-1. These aquatic toxicity values are designed to be protective of the aquatic community, including most fish and benthic invertebrate species, and some aquatic plants. For the purposes of table presentation, toxicity benchmarks that are hardness-dependant are shown based on a hardness of 100 mg/L (a hardness value typical for the site). Chemicals without surface water toxicity benchmarks were not included in the HQ calculations and will be discussed qualitatively in the uncertainties section.

5.1.3 Risk Characterization

Table 5-2 summarizes the estimated HQs for aquatic receptors from direct contact with surface water. HQs based on the acute and chronic toxicity benchmarks are displayed as a range (acute HQ to chronic HQ). In this table, if either the acute or chronic HQ was above one, the HQ range has been shaded grey.

[1] Hardness was calculated from measured calcium and magnesium concentrations using the following equation: *Hardness, mg/L as* $CaCO_3$ *= [2.497 x Ca, mg/L] + [4.118 x Mg, mg/L]* (Water Treatment Guide, 2004)

As seen in Table 5-2, the highest HQs were calculated for samples collected from the Lower Lake, with HQs above an acute level of concern for antimony, selenium, and cadmium, and a chronic level of concern for lead, thallium, and manganese. For the Upper Lake and marsh area, most HQs were below one. Chronic HQs for manganese in two samples from the central portion of the marsh area and lead in two samples from the northern portion of the Upper Lake were above a level of concern. For Prickly Pear Creek, almost all HQs were below one. Chronic HQs for selenium were slightly above a level of concern in two Prickly Pear Creek samples downstream of the site.

Acute and chronic HQs in the Canyon Ferry Reservoir and the upstream Prickly Pear Creek reference locations were below one for most metals. However, chronic HQs for selenium were above a level of concern for the Canyon Ferry Reservoir reference area. As discussed in Section 4.3.1, this indicates that the estimated HQs for selenium are similar to reference conditions and HQ estimates at on-site locations should be interpreted cautiously. Zinc HQs were above a level of concern at only the upstream Prickly Pear Creek station which indicates that elevated zinc concentrations in surface water are not site-related.

5.1.4 Species-Specific Toxicity Assessment for Surface Water

Evaluation of surface water concentration data by comparison to aquatic toxicity benchmarks is useful in assessing risks to the aquatic community as a whole, but does not provide information on which species may be most at risk. Figures 5-1a through 5-1f compare the measured surface water concentrations of metals for which HQs exceeded a level of concern based on community-wide benchmarks (Table 5-2) to toxicity values derived for a number of different species of fish and aquatic invertebrate receptors. In these figures, toxicity values for fish are shown on the left side, while toxicity values for benthic invertebrates are shown on the right side. Toxicity values for fish and benthic invertebrates were compiled from either the chemical-specific National Ambient Water Quality Criteria (AWQC) reports, the 1995 AWQC Updates report (USEPA, 1996), or Suter and Tsao (1996). Species-specific toxicity values are summarized in Appendix C and derived as follows:

Acute Toxicity Value = Species or genus mean LC50 / 2
Chronic Toxicity Value = Species or genus mean chronic value

Because the toxicity of cadmium and lead depend on water hardness, surface water concentrations (both the toxicity values and the measured field values) were normalized to a hardness of 100 mg/L, which is a hardness value typical for the site. This normalization was achieved using the following equation:

$$C(100) = C(H) \times TRV(100) / TRV(H)$$

where:

C(100) = normalized concentration at a hardness of 100 mg/L
C(H) = original concentration at a hardness = H
TRV(100) = Toxicity value at a hardness of 100 mg/L
TRV(H) = Toxicity value at a hardness = H

As seen in Figures 5-1a through 5-1f, measured surface water concentrations of metals in the on-site lakes and in Prickly Pear Creek were below all or most species-specific toxicity values for both fish and benthic invertebrates. For cadmium (Figure 5-1b), dissolved surface water concentrations in Lower Lake were higher than acute and chronic toxicity values for several trout species including rainbow, brown, and brook trout, and chronic toxicity values for *Daphnia* and *Hyalella*. For antimony (Figure 5-1a) and thallium (Figure 5-1f), dissolved surface water concentrations in Lower Lake were higher than the acute toxicity value for the *Hydra* and the chronic toxicity value for the fathead minnow, respectively.

For Lower Lake, these graphs illustrate that several metals in surface water were above levels expected to have adverse effects on a number of different species of both fish and benthic invertebrates in the aquatic community.

For Upper Lake and the marsh area and Prickly Pear Creek, chronic HQs for selenium, manganese, and lead were above one at several stations, but the measured surface water concentrations were not above any species-specific toxicity value. However, the underlying toxicity datasets for these metals are limited, both in the number of species evaluated and the types of studies available (e.g., acute data but no chronic data). Therefore, it is possible that species which are more sensitive than those for which toxicity data are available may be adversely impacted at these locations due to elevated levels of selenium, manganese, and lead in surface water.

5.1.5 Conclusions for Direct Contact of Aquatic Receptors with Surface Water

The following risk conclusions are drawn for aquatic receptors from direct contact with surface water based on a consideration of the number of exceedences within each exposure area (HQs > 1), the magnitude of the exceedences, and a comparison of site values to reference areas:

- For Lower Lake, HQ values indicate that surface water in the lake may be acutely toxic to the aquatic community due to elevated concentrations of several metals including cadmium, antimony, thallium, and selenium. Surface water HQ values for Lower Lake are higher than the other on-site lake (Upper Lake) and the off-site reference (Canyon Ferry Reservoir). Surface water concentrations of several metals are above levels associated with acute and chronic toxicity for several fish and benthic invertebrate species.

- For the Upper Lake and marsh area, HQ values indicate that manganese and lead in a few locations may be adversely impacting the aquatic community in these areas. While some more sensitive species may be impacted at a few locations due to elevated surface water concentrations of manganese and lead, HQ values for all other metals are below a level of concern. Because elevated HQs are limited to only a few stations, it is unlikely that aquatic receptor populations in the Upper Lake and marsh areas are adversely impacted due to surface water.

- For Prickly Pear Creek, HQ values indicate that some aquatic receptor species in the creek may be slightly impacted due to elevated surface water concentrations of selenium downstream of the East Helena site. It is unlikely that aquatic receptor populations are adversely impacted in Prickly Pear Creek due to surface water because HQ values for all other metals are below a level of concern and because the magnitude of the selenium exceedances are relatively low (chronic HQs of 2).

It is important to remember that this surface water evaluation was based on samples collected during one sampling event in 2003 and may not represent the variability in concentrations as a function of time.

5.2 HQ Approach for Direct Contact of Benthic Invertebrates with Bulk Sediment

The risk evaluation for sediment-dwelling benthic invertebrates from bulk sediment was based on an HQ approach. As stated previously, HQ is the ratio of the estimated exposure to a screening-level toxicity benchmark and was calculated as follows:

$$HQ = Conc_{Sed} / TB_{Sed}$$

where:

$Conc_{Sed}$ = chemical concentration in bulk sediment (mg/kg)
TB_{Sed} = chemical toxicity benchmark for bulk sediment (mg/kg)

Recall that if the HQ exceeds one, the risk of adverse effect in the exposed organisms is of potential concern. If the value of an HQ is less than or equal to one, risk of unacceptable adverse effects in the exposed organisms is judged to be acceptable.

5.2.1 Exposure Assessment

Benthic invertebrates that spend some or most of their life cycle within the sediment substrate are exposed to chemicals through direct contact with sediments in Prickly Pear Creek, the Lower Lake, and the Upper Lake/Marsh Area.

For the purposes of this evaluation, bulk sediment data were restricted to those samples collected during the 2003 ecological field investigation in order to assess potential risks based on current site conditions. Sediment samples were collected from each sampling station (Figure 3-1). In most cases, sediment data were collected from a depth of 0 to 6 inches, where most benthic invertebrates are expected to live.

Although concentrations of chemicals in sediment are usually not as time-variable as concentrations in surface water, concentrations do fluctuate as contaminated material is added or removed by surface water flow. Therefore, exposure to sediments is usually best characterized as a distribution of individual values at a specific location. Because only one sediment sample was collected at each sampling location, risks were calculated for each sample for each chemical at each location.

5.2.2 Toxicity Assessment

Toxicity benchmark values for the protection of benthic invertebrates from direct contact with chemicals in sediment are available from several sources. Each of the sources evaluated in deriving sediment toxicity benchmarks is described briefly in Appendix B. This appendix also describes the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available.

For each chemical analyzed in sediment, a threshold effect concentration (TEC) and a probable effect concentration (PEC) were identified. Sediment toxicity should be observed only rarely below the TEC and is expected to occur frequently above the PEC. Table 5-3 presents the toxicity benchmark values for invertebrates from direct contact with bulk sediment. Chemicals without bulk sediment toxicity benchmarks were not included in the HQ calculations and will be discussed qualitatively in the uncertainties section.

5.2.3 Risk Characterization

Table 5-4 summarizes the estimated HQs for benthic invertebrates from direct contact with bulk sediment. HQs based on the PEC and TEC toxicity benchmarks are displayed as a range (PEC HQ to TEC HQ). In this table, if either the PEC or TEC HQ was above one, the HQ range has been shaded grey. As seen, HQs were above one for most site stations for multiple metals, with HQs exceeding 100 at many locations. Sediment samples from Prickly Pear Creek tended to have lower HQs than samples from the on-site lakes and marsh area. However, HQs for sediments from Prickly Pear Creek were also above a level of concern for several metals.

The arsenic HQ for one sample from the Canyon Ferry Reservoir reference area was slightly above a level of concern. As discussed in Section 4.3.1, this indicates that the estimated risks from arsenic at on-site locations should be interpreted cautiously. HQs for cadmium, copper, lead, and zinc at the upstream Prickly Pear Creek reference location were slightly elevated based on the TEC benchmark which indicates that historical mining activities may have influenced sediment quality upstream of the site. However, an HQ comparison of upstream to downstream demonstrates that site-related activities contribute appreciably to concentrations of these metals in bulk sediment.

5.2.4 Conclusions for Direct Contact of Benthic Invertebrates with Bulk Sediment

Based on these HQ estimates for bulk sediment, it appears that widespread and severe toxicity may be occurring in sediment-dwelling benthic invertebrate populations that reside in the on-site lakes and marsh area and in Prickly Pear Creek. However, in considering these estimates of potential risk, it is important to understand that the sediment toxicity benchmarks for benthic invertebrates are based on studies in which multiple contaminants were present and assumes all of the observed toxicity was due to the contaminant of interest, even though other contaminants in the sediment may be associated with observed toxicity. Therefore, there is uncertainty that exceedence of the benchmark for a particular chemical will actually cause toxicity.

In addition, there may be differences between East Helena sediments and those used to establish the toxicity benchmarks, which could influence the relative toxicity of chemicals in the sediments. Examples of site-specific sediment parameters that may affect toxicity include particle size, organic carbon content, and pH. If only a fraction of the total amount of bulk chemical in sediment is biologically available due to site-specific conditions, the observed toxicity in the receptor will be lower than predicted.

5.3 HQ Approach for Direct Contact of Benthic Invertebrates with Sediment Porewater

Adverse effects to sediment-dwelling benthic invertebrates from contaminants in sediment are likely to be mediated primarily by chemicals that have dissolved into sediment porewater from the bulk sediment. Thus, another more direct approach for evaluating toxicity from chemicals in sediment is to measure the concentrations in the sediment porewater and compare those concentrations to water-based toxicity values. For this approach, the HQ is the ratio of the measured porewater concentration to an appropriate water toxicity benchmark, as follows:

$$HQ = Conc_{pw} / TB_{pw}$$

where:

$Conc_{pw}$ = chemical concentration in sediment porewater (ug/L)
TB_{pw} = chemical toxicity benchmark for water (ug/L)

5.3.1 Exposure Assessment

Since there may be both spatial and temporal variability in sediment porewater concentrations at any specific sampling station, exposure to benthic invertebrates is usually best characterized as a distribution of concentration values at a specific location. As part of the 2003 ecological field investigation sediment porewater samples were collected from a subset of the sampling stations (see Table 3-2). For Prickly Pear Creek, sediment porewater was collected using a micro-push point sampler (mini-piezometer). For the on-site lakes and marsh area and the Canyon Ferry Reservoir, bulk sediment samples were spun down using a centrifuge and the resulting supernatant was collected and filtered. As part of this investigation, only one sediment porewater sample was collected from each sampling location, so exposure was based on the measurements from a single sample. As noted previously, because toxicity to aquatic receptors from water exposure is dominated by the level of dissolved chemicals, exposures to metals in sediment porewater were evaluated using dissolved concentrations.

5.3.2 Toxicity Assessment

Toxicity benchmarks specifically for the protection of benthic invertebrate communities from contaminants in sediment porewater are not generally available, so benchmarks for the protection of aquatic communities (including fish, benthic invertebrates, aquatic plants, etc.) from direct contact with chemicals in surface water were used (Table 5-1). Appendix B provides detailed information on the sources and selection procedure for these surface water toxicity benchmarks. Hardness-dependant benchmarks were calculated based on the calculated hardness in each sediment porewater sample.

5.3.3 Risk Characterization

Table 5-5 summarizes the estimated HQs for benthic invertebrates from direct contact with sediment porewater. Results are displayed as a range (acute HQ to chronic HQ). In this table, if either the acute or chronic HQ was above one, the HQ range has been shaded grey. For Lower Lake, concentrations of several metals were above acute and/or chronic toxicity levels, with the highest HQs for antimony and arsenic. For Upper Lake and the marsh area, chronic HQs for iron, manganese, and lead were above a level of concern in one or more samples. Sediment porewater concentrations of manganese, selenium, and cadmium from several stations along Prickly Pear Creek were also above chronic toxicity benchmarks with HQ values typically at or below 5.

Chronic manganese HQs for Canyon Ferry Reservoir reference locations were slightly above a level of concern. As discussed in Section 4.3.1, this indicates that the estimated risks from manganese could potentially be too high and hence HQ estimates at on-site locations should be interpreted cautiously. Chronic cadmium and manganese HQs for the upstream Prickly Pear Creek reference location were also above one indicating that elevated concentrations of these metals in sediment porewater may not be due to site-related activities.

5.3.4 Species-Specific Toxicity Assessment for Sediment Porewater

As discussed above, the benchmarks used to estimate sediment porewater HQs (Table 5-5) were based on surface water screening values derived to be protective of most aquatic receptors, including fish and aquatic plants. Because of this, an HQ above one does not necessarily indicate that sediments are adversely impacting benthic invertebrate populations. For example, the Final Chronic Value for aluminum was lowered from 748 ug/L based on *Daphnia magna* to 87 ug/L to protect brook trout and striped bass. Because brook trout and striped bass are not representative of invertebrate species, a chronic value of 748 ug/L is likely to be more appropriate for use in the sediment porewater evaluation. If the aluminum HQ for the Lower Lake porewater sample were recalculated based on a chronic toxicity value of 748 ug/L, the resulting chronic HQ would be below one.

In order to further evaluate the significance of HQ values above a level of concern to benthic invertebrate species, sediment porewater concentrations were compared to toxicity values derived for a number of different species of benthic invertebrates. Figures 5-2a through 5-2f compare the measured sediment porewater concentrations of metals for which HQs exceeded a level of concern to benthic invertebrate toxicity values. These toxicity values were compiled from either the chemical-specific AWQC reports or Suter and Tsao (1996). For metals in which toxicity is hardness-dependant, both the toxicity values and the measured field values were normalized to a hardness of 100 mg/L. Details on the derivation of the acute and chronic toxicity values and the hardness normalization were provided previously in Section 5.2.4.

For Lower Lake, sediment porewater concentrations of arsenic (Figure 5-2b) were higher than acute and chronic toxicity values for the amphipod and several cladoceran species. The Genus Mean Acute Values (GMAVs) for these invertebrate species are based on LC50 values ranging from 874 to 2,690 ug/L. The measured arsenic concentration of 2,530 ug/L in sediment porewater from Lower Lake is within the range where mortality would be expected. Measured sediment porewater concentrations of antimony (Figure 5-2a) and cadmium (Figure 5-2c) in Lower Lake were also above acute and chronic toxicity values for several invertebrate species. These graphs illustrate that several metals in sediment porewater from Lower Lake were above levels expected to have severe adverse effects on a number of different species of benthic invertebrates.

For Upper Lake and the marsh area and Prickly Pear Creek, measured sediment porewater concentrations of metals were below all or most of the species-specific toxicity values for benthic invertebrates. Sediment porewater concentrations of cadmium (Figure 5-2c) in Prickly Pear Creek were higher than two species-specific chronic toxicity values; however, measured concentrations were similar to the upstream reference which suggests that elevated concentrations may not be due to site-related activities. While chronic HQs (Table 5-5) for manganese, iron, and lead were above one at several stations within these exposure areas, the measured sediment porewater concentrations were similar to reference or were below species-specific toxicity values. However, the underlying toxicity datasets for these metals are limited, both in the number of species evaluated and the types of studies available (e.g., acute data but no chronic data). Therefore, it is possible that more sensitive invertebrate species exist and may be adversely impacted at these locations due to elevated levels of manganese, iron, and lead in sediment porewater.

5.3.5 Conclusions for Direct Contact of Benthic Invertebrates with Sediment Porewater

Based on these estimated HQs for sediment porewater, the following conclusions are drawn:

- Sediment-dwelling invertebrates in Lower Lake are likely to be adversely impacted due to elevated concentrations of several metals in sediment porewater. Based on a review of the toxicity data used to derive the screening-level aquatic benchmarks, the metals of primary concern in sediment porewater are arsenic, antimony, and cadmium.

- For the Upper Lake and marsh area and Prickly Pear Creek, chronic HQs indicate that invertebrates may be adversely impacted at several locations due to several metals. While measured sediment porewater concentrations are not higher than any invertebrate-specific toxicity values, several of the toxicity datasets are limited and may not include effects on more sensitive species. It is not possible to assess whether the frequency and magnitude of chronic effects on sensitive species would influence benthic invertebrate populations in these exposure areas.

- HQ estimates based on sediment porewater (Table 5-5) are much lower than those based on bulk sediment (presented previously in Table 5-4). This indicates that although bulk metal concentrations in sediment may be high, only a small fraction of these metals are in a biologically available form and able to dissolve into the sediment porewater.

It is important to remember that this sediment porewater evaluation was based on samples collected during one sampling event in 2003 and may not represent the variability in concentrations as a function of time.

5.4 Site-Specific Sediment Toxicity Testing with Benthic Invertebrates

One way to help reduce the uncertainty associated with risk predictions based on the HQ approach is to perform direct toxicity testing using site-specific media. Tests of this type have been performed to investigate the toxicity of site sediments on benthic organisms, using sediment samples collected from one location in the Lower Lake, six locations in the Upper Lake and marsh area, and two reference locations in Canyon Ferry Reservoir. For each sampling station, a 10-day subchronic survival and growth toxicity test using the amphipod (*Hyalella azteca*) was conducted in accord with standard protocols. Table 5-6 summarizes the detailed toxicity test results.

As seen, statistically significant decreases in survival were noted for organisms exposed to sediments from Lower Lake compared to the laboratory control. These findings strongly support the conclusion that sediments in the Lower Lake are likely to be causing adverse effects on populations of benthic receptors that may reside there. Sediment toxicity tests do not provide information on which chemicals are most likely to be responsible for the effects, or what the main source of the sediment contamination may be. However, HQ calculations based on measured sediment porewater concentrations in Lower Lake suggest that elevated levels of arsenic, and to a lesser extent antimony and cadmium, may account for the observed toxicity. Exposure to sediments from the Upper Lake and marsh area did not adversely impact survival or growth compared to the laboratory control or the Canyon Ferry Reservoir reference.

5.5 Benthic Invertebrate Community Evaluations

Effects of chemical stressors on an ecosystem can sometimes be evaluated by direct observation of the density and diversity of species present in the ecosystem. At the East Helena site, observations on the benthic invertebrate community structure were collected as part of the 2003 ecological field investigation. Representative invertebrate samples were collected from five stations in Prickly Pear Creek and two stations in the Upper Lake and marsh area. For Prickly Pear Creek, station PPC-1 was located upstream of the site and served as a reference location. Canyon Ferry Reservoir was also sampled to serve as a reference location for the Upper Lake. For each sample, invertebrates were identified to the genus level and the relative abundance of each taxon was determined. Biological tolerance values were derived based on Rapid Bioassessment Protocols (RBP) for rivers and streams (Barbour et al., 1999; Bukantis, 2004).

5.5.1 Comparison of Community Metrics to Reference

Appendix D provides a detailed summary of the benthic invertebrate abundance and relative tolerance rankings for benthic invertebrate species observed at each station. Figure 5-3 presents metrics of invertebrate diversity and density for each station. In the upper panel of Figure 5-3, diversity is plotted based on total number of species and the number of Ephemeroptera, Plecoptera, and Tricoptera (EPT) species, which tend to be more sensitive to contamination due to metals. In the lower panel of Figure 5-3, the density estimates were based on the sum across relative abundance rankings for each species and should be interpreted as a qualitative assessment metric.

For the Upper Lake and marsh area, the community samples collected contained invertebrates that were typical of standing water organisms (USEPA, 2004). Unfortunately, at the time of sampling, the Canyon Ferry Reservoir site was at low water conditions and the resulting community sample was not a suitable reference for the Upper Lake and marsh area samples. Because benthic invertebrate community data from a suitable reference area were not available, it is not possible to draw conclusions as to whether the diversity and/or density of invertebrates are similar to what is expected. However, the fact that a number of different benthic taxa were observed suggests the sediments from the Upper Lake and marsh area are suitable for at least some species of invertebrates.

For Prickly Pear Creek, estimates of diversity and density shown in Figure 5-3 for all of the sampling stations visually appear to be lower than the upstream reference station (PPC-1). However, this supposition does not account for natural community variability within each location. Because community results were only available for one sample from one sampling event, it was not possible to determine if site metric estimates were in fact different from the reference station. Additional community samples would be needed which span multiple locations and time periods to rule out the effects of other potential variables or to establish community trends and expected variability over time within Prickly Pear Creek.

Assuming that density and diversity estimates were truly lower in the downstream portions of Prickly Pear Creek compared to upstream, it is important to understand what factors may be contributing to these decreases. Benthic invertebrate community density and diversity estimates may be influenced by a variety of factors such as habitat quality, food availability, predation, and environmental contamination. This evaluation focused on the potential influence of organic and metal pollutants in Prickly Pear Creek. For each sample, benthic invertebrate species were assigned a relative tolerance ranking to organic pollution and metals pollution (Bukantis, 1998). Figure 5-4 presents the percent change in the relative abundance of invertebrates within three tolerance classes compared to the upstream reference station. In Figure 5-4, the upper and lower panels present the change in abundance based on tolerance to organic pollutants and metal pollutants, respectively. As seen, there was a consistent decrease in the relative abundance of species that were intolerant to organic pollution and an increase in the relative abundance of species that were moderately tolerant or tolerant to organic pollution for nearly all Prickly Pear Creek stations. In addition, there appeared to be a consistent increase in the relative abundance of species that were moderately tolerant or tolerant to metal pollution. However, changes in the relative abundance of metals intolerant species were not consistent from station to station.

5.5.2 Comparison of Community Metrics to Measured Concentrations

In order to assess the influence of metals in Prickly Pear Creek on the benthic invertebrate community, measured bulk sediment and sediment porewater concentrations for several metals were compared to each of the available community metrics. Figure 5-5 provides an example of these comparisons for cadmium in bulk sediment (top panels) and sediment porewater (bottom panels). As seen, bulk sediment concentrations varied widely from station to station but did not appear to correlate well with observed differences in the community metrics. For example, bulk sediment concentrations of cadmium were similar for stations PPC-1 and PPC-2 but community density and diversity metrics at station PPC-2 decreased about 40% compared to PPC-1. While bulk sediment concentrations increased by almost a factor of 4 from station PPC-2 to station PPC-3 (6.0 mg/kg to 22.8 mg/kg), community metrics were similar both stations. A similar pattern was seen for most metals in bulk sediment and for sediment porewater. This suggests that while metals in Prickly Pear Creek may be influencing benthic invertebrate communities, other non-metal factors are probably more important.

Overall, the benthic invertebrate community evaluation indicates that the density and diversity may be impacted in Prickly Pear Creek compared to the upstream reference area. The observed changes in the relative abundance could be due to either organics or metals as indicated by an increase in more tolerant species at most stations. However, a comparison of measured concentrations of metals in bulk sediment and sediment porewater suggests that metals alone do not account for the variability in the community metrics between stations and are likely to be small compared to other potential factors (e.g., nutrient availability).

It is important to recognize that a comparison of reference community metrics to site community metrics is limited by the fact that the reference area may not account for all of the important habitat variables that can influence benthic invertebrate community metrics. As such, comparisons to reference do not always establish firm cause-and-effect conclusions regarding the impact of sediment contamination on the invertebrate community. For example, station PPC-5 was located downstream in a prairie/plains ecoregion whereas the reference station PPC-1 is located in a foothills ecoregion. Because these stations are in different ecoregions, it is not possible to distinguish between population-level shifts due to site-related impacts and those due to natural community differences between ecoregions.

5.6 Evaluation of Fish Exposures via Ingestion of Aquatic Prey Items

As noted in the site conceptual model (Figure 4-1), fish may be exposed via ingestion of aquatic prey items that have taken up metals from surface water or sediment.

5.6.1 Toxicity Assessment

Historically, the toxicity data for oral exposures by fish were too limited to derive meaningful toxicity benchmark values for dietary exposures. However, new data from several trout feeding studies allow for the derivation of an oral threshold value for the ingestion of arsenic in the diet. Based on the results of these trout studies, it appears that the threshold for growth inhibition due to ingestion of arsenic is approximately 40 ug As/g diet on a dry weight basis (USEPA, 2004d). While other metals have not been as extensively evaluated, the Clark Fork River Ecological Risk Assessment (USEPA, 2001) provided screening-level oral toxicity benchmarks for fish for cadmium, copper, lead, and zinc. Table 5-7 (Part A) provides a summary of the available oral toxicity benchmarks (dry weight) for fish.

5.6.2 Exposure Assessment

Data on metal concentrations in the aquatic prey items for fish were collected as part of the 2003 ecological field investigation. Specifically, the stomach contents of three rainbow trout and benthic invertebrates composite samples were collected from the Upper Lake and marsh area and analyzed for arsenic, cadmium, copper, lead, selenium, and zinc. While the 2003 investigation did not collect aquatic food items from Prickly Pear Creek, USFWS (1997) provides measured concentrations of arsenic, cadmium, copper, lead, selenium, and zinc for benthic invertebrates from Prickly Pear Creek upstream and downstream of the East Helena site. Table 5-7 (Parts B and C) present the measured tissue concentrations on a dry weight basis for aquatic prey items from the Upper Lake/Marsh Area and Prickly Pear Creek, respectively. No measured prey item data were available for the Lower Lake.

5.6.3 Risk Characterization and Conclusions for Fish Ingestion of Aquatic Prey Items

For the Upper Lake and marsh area (Table 5-7 Part B), measured aquatic invertebrate concentrations were compared to measured concentrations in the Canyon Ferry reference area. As seen, concentrations of cadmium, copper, lead, and zinc on-site appear to be higher than the reference area (identified as cells with heavy bold outline). However, due to the limited number of samples, it was not possible to determine if this apparent difference was statistically significant. Measured stomach content data were not available from the Canyon Ferry reference area, so a comparison of site data to reference could not be performed. Measured concentrations of copper and lead in aquatic invertebrates from the northern portion of Upper Lake and lead in the stomach contents of a rainbow trout collected from Upper Lake were above the screening-level oral toxicity benchmarks (identified as shaded cells). These screening-level comparisons suggest that fish which feed on aquatic invertebrates in Upper Lake, particularly the northern portion of this lake, may be adversely impacted due to elevated levels of lead and copper in prey items.

For Prickly Pear Creek (Table 5-7 Part C), measured concentrations in invertebrate composite and stonefly larvae samples collected downstream of the East Helena site were compared to measured concentrations in samples collected upstream of the site. As seen, geometric mean concentrations of cadmium, copper, lead, and zinc in stonefly larvae from Prickly Pear Creek below the East Helena site were statistically higher than concentrations measured above the site (identified as cells with heavy bold outline). However, measured concentrations did not exceed any of the available screening-level oral toxicity benchmarks. These screening-level comparisons suggest that, while there is evidence that certain aquatic invertebrates may have elevated tissue levels, it is unlikely that ingestion of these prey items would adversely impact fish populations in Prickly Pear Creek.

5.7 Evaluation of Fish Exposures via Incidental Ingestion of Sediment

It is not believed that fish intentionally swallow inorganic sediments, but a few reports were located which indicate that sand or small stones are occasionally found in the stomach content of trout (Papageorgiou et al. 1984) and suckers (Carl 1936, Macaphee 1960). Even though the amount of sediment ingested may be small, this could be a source of significant exposure because the concentration of metals in sediments is substantially higher than the concentration in aquatic prey items, particularly in the on-site lakes and marsh area.

5.7.1 Toxicity Assessment

No data were located that would allow derivation of oral benchmarks for fish from ingestion of sediment. Therefore, screening-level sediment benchmarks were estimated from the dietary benchmarks for fish (presented previously in Table 5-7) as follows:

$$\text{Oral Benchmark}_{sed} = \text{Oral Benchmark}_{diet} / (f * RBA)$$

where:

f = Estimated fraction of the diet that is composed of sediment
RBA = Relative Bioavailability of metals in sediment compared to dietary materials

No quantitative data were located on the fraction of the total diet of a fish that is composed of inorganic sediment particles. However, the Clark Fork River Ecological Risk Assessment indicated that this fraction may range from 2% for trout to 5%-10% for suckers (USEPA, 2001). For the purposes of this screening-level assessment, a value of 5% was assumed.

Similarly, no quantitative data were located on the RBA of metals in sediments compared to that in normal food items. Based on the expectation that metals in sediment particles are likely to be less well absorbed than metals in benthic organisms, a value of 50% was assumed for the RBA.

Table 5-8 (Part A) provides a summary of the estimated oral toxicity benchmarks for fish from ingestion of sediment.

5.7.2 Exposure Assessment

Data on the bulk metals concentrations in sediment were collected as part of the 2003 ecological field investigation. Table 5-8 (Part B) provides a summary of the measured concentrations for arsenic, cadmium, copper, lead, and zinc in bulk sediments from the Upper Lake and marsh area, Lower Lake, Canyon Ferry Reservoir, and Prickly Pear Creek both upstream and downstream of the East Helena site. As seen, in nearly all cases, measured bulk sediment concentrations for both for the on-site lakes and Prickly Pear Creek were higher than their respective reference areas. In this table, measured bulk sediment concentrations that exceed the toxicity benchmark are shown as shaded cells.

5.7.3 Risk Characterization and Conclusions for Fish Ingestion of Sediment

For Lower Lake, measured bulk cadmium concentrations in one sample, and bulk arsenic and lead concentrations in all samples were above the oral sediment benchmarks. Bulk sediment concentrations of copper and zinc did not exceed screening-level sediment benchmark values for oral exposures in fish in any Lower Lake sample. For the Upper Lake and marsh area, measured bulk sediment concentrations of arsenic, cadmium, copper, and zinc in all samples were below the oral sediment benchmarks. Measured concentrations of lead at two stations in the northern portion of Upper Lake were above the sediment benchmark. These screening-level comparisons indicate that fish populations inhabiting the Lower Lake or the northern areas of the Upper Lake may by negatively affected due to the incidental ingestion of arsenic, lead, and cadmium in sediment.

For Prickly Pear Creek, measured bulk sediment concentrations in all samples were below the sediment benchmark for all metals. These screening-level comparisons suggest that it is unlikely that incidental ingestion of sediment would adversely impact fish populations in Prickly Pear Creek.

5.8 Evaluation of Tissue Burdens in Aquatic Organisms

Another way to estimate risks to aquatic organisms is to compare the measured tissue levels of metals in site samples to literature-derived aquatic tissue concentrations which represent levels with and without evidence of adverse effects. This approach has the advantage that it integrates exposures over multiple sources (surface water, sediment, food web), and accounts for any site-specific factors that might increase or decrease exposure compared to laboratory conditions.

5.8.1 Toxicity Assessment

Jarvinen and Ankley (1999) provide a compilation of studies that identify effect levels and no effect levels of organic and inorganic chemicals, expressed in terms of aquatic tissue concentrations on a wet weight basis. For this screening-level assessment, the tissue burden-based toxicity benchmark was defined as the highest no effect level (NEL_{high}) that was below the lowest effect level (EL_{low}) for endpoints related to growth, reproduction, and mortality. Table 5-9 provides a summary of the available tissue burden-based toxicity benchmarks for fish and aquatic invertebrates for each of the metals analyzed in aquatic tissues. When available, benchmarks are presented both for whole body residues and for organ-specific residues. If only an EL_{low} was available (e.g., copper in fish kidney), the screening-level benchmark value was equal to the $EL_{low}/2$. This adjustment factor was selected based on the observation that the NEL_{high} and the EL_{low} presented in Table 5-9 were usually within a factor of two. No tissue burden-based toxicity benchmarks were available for aquatic plants.

5.8.2 Exposure Assessment

Data on metal concentrations in aquatic invertebrates, fish, and aquatic plants were collected as part of the 2003 ecological field investigation. Aquatic tissue samples from the Upper Lake and marsh area were analyzed for arsenic, cadmium, copper, lead, selenium, mercury[2], and zinc. While the 2003 investigation did not collect aquatic food items from Prickly Pear Creek, USFWS (1997) provides measured concentrations of arsenic, cadmium, copper, lead, selenium, mercury[2], and zinc for aquatic invertebrates and fish from Prickly Pear Creek upstream and downstream of the East Helena site. Table 5-10a and 5-10b present the measured tissue burdens

[2] Mercury was only measured in fish tissue (see Appendix A).

on a wet weight basis for aquatic receptors from the Upper Lake/Marsh Area and Prickly Pear Creek, respectively. No measured tissue data were available for the Lower Lake.

5.8.3 Risk Characterization and Conclusions for Tissue Burdens in Aquatic Organisms

For Upper Lake/Marsh Area (Table 5-10a), measured tissue concentrations of most metals in aquatic invertebrates, forage fish, and aquatic plants appeared to be higher than concentrations from the Canyon Ferry reference area (identified as cells with heavy bold outline). However, due to the limited number of samples, it was not possible to determine if this apparent difference was statistically significant. In addition, tissue burdens for several metals in aquatic invertebrates and fish were above the NEL_{high} in nearly all samples, including samples from the reference area (identified as shaded cells). As discussed in Section 4.3.1, this suggests that the NEL_{high} may not account for site-specific factors influencing toxicity from metals in aquatic receptors at the East Helena site and estimated at on-site locations should be interpreted cautiously.

For Prickly Pear Creek (Table 5-10b), measured tissue concentrations for most samples collected downstream of the East Helena site were similar to or below concentrations measured upstream of the site. Only measured concentrations of cadmium, copper, lead, and zinc in stonefly larvae from Prickly Pear Creek downstream of the site were statistically higher than concentrations measured upstream of the site (identified as cells with heavy bold outline). Tissue burdens for several metals in aquatic invertebrates and fish were above the NEL_{high} in many instances, including samples collected from upstream of the site (identified as shaded cells). This suggests that the elevated levels may not be due to site-related activities and/or that these tissue burden-based benchmarks may not account for site-specific factors influencing toxicity from metals in aquatic receptors at the East Helena site. Predicted risks in downstream portions of Prickly Pear Creek should be interpreted cautiously.

5.9 Weight of Evidence Conclusions for Aquatic Receptors

The best approach for deriving reliable conclusions regarding risk to a group of ecological receptors is to combine the findings across all of the evaluation methods for which data are available, taking the relative strengths and weaknesses of each method into account. This approach is referred to as a weight of evidence evaluation.

For each aquatic receptor exposure area (Lower Lake, the Upper Lake and marsh area, Prickly Pear Creek), the individual lines of evidence, the overall conclusions, and confidence level based on the weight of evidence evaluation are summarized below.

5.9.1 Lower Lake

Fish

Two lines of evidence are available to assess potential risks to fish from the Lower Lake. The HQ evaluation for surface water based on aquatic community-based toxicity benchmarks indicates that aquatic receptors residing in Lower Lake are probably adversely impacted due to presence of several metals above levels associated with acute toxicity. In particular, dissolved surface water concentrations of cadmium exceed levels associated with toxicity for several trout species including rainbow, brown, and brook trout. The screening-level comparison of measured bulk sediment concentrations to oral sediment benchmarks for fish suggests that sediment levels of arsenic, lead, and cadmium are potentially harmful to fish due to incidental ingestion.

Based on these two lines of evidence, it is concluded that the risk of population-level effects to fish in Lower Lake is moderately high. However, because only two lines of evidence are available to support this conclusion and risk estimates are based on a limited datasets, confidence in this conclusion is low to moderate.

<u>Benthic Invertebrates</u>

Four lines of evidence are available to assess potential risks to benthic invertebrates from the Lower Lake. The HQ evaluations for direct contact with surface water, bulk sediment, and sediment porewater all indicate that benthic invertebrates residing in the lake are likely to be severely impacted due to presence of several metals above levels associated with toxicity. This conclusion is supported by the results of the site sediment toxicity test. Sediments from Lower Lake caused a statistically significant increase in *Hyalella azteca* mortality compared to the laboratory control. These test results are consistent with the species-specific evaluation for sediment porewater which concluded that elevated arsenic and to a lesser extent, antimony and cadmium, in sediment porewater from Lower Lake was likely to adversely affect several species of benthic invertebrates.

Based on these lines of evidence, it is concluded that the risk of population-level effects to benthic invertebrates in Lower Lake is high. Because multiple lines of evidence support this conclusion, confidence in this conclusion is high.

5.9.2 Upper Lake and Marsh Area

<u>Fish</u>

Four lines of evidence are available to assess potential risks to fish from the Upper Lake and marsh area. For most metals, the HQ evaluation for direct contact with surface water based on aquatic community-based toxicity benchmarks indicates that aquatic receptors residing in these areas are not likely to be adversely impacted. While surface water concentrations of manganese and lead exceed aquatic community-based toxicity benchmarks, concentrations are below all available species-specific toxicity values for fish. However, the underlying toxicity datasets for the species-specific toxicity values are limited, and it is possible that more sensitive species may be impacted at these locations. The screening-level evaluation of fish exposure from ingestion pathways indicates that elevated levels of copper and lead in prey items and lead in sediment in the northern portion of the Upper Lake may adversely impact fish. While tissue burden comparisons suggest that fish tissue levels on-site may be elevated relative to reference, it is difficult to determine if on-site tissue burdens are above a level of concern due to uncertainties related to the tissue burden toxicity benchmarks (i.e., reference samples also exceed benchmarks).

Based on these lines of evidence, it is concluded that, while fish may be adversely impacted at a few stations in the northern areas of the Upper Lake, the risk of population-level effects to fish in Upper Lake and the marsh area is probably minimal to low. Although multiple lines of evidence are available, risk estimates are based on limited exposure and toxicity datasets, so confidence in this conclusion is only moderate.

Benthic Invertebrates

Six lines of evidence are available to assess potential risks to benthic invertebrates from the Upper Lake and marsh area. The HQ calculations for surface water and sediment porewater and comparisons with species-specific aqueous toxicity values indicate that, while some more sensitive species may be impacted due to elevated metals at some locations, benthic invertebrate populations are not likely to be adversely impacted in the Upper Lake and marsh area. This conclusion is supported by the results of the sediment toxicity tests conducted with samples from six separate locations in the Upper Lake and marsh area. These tests demonstrate that direct exposure of *Hyalella azteca* to sediments from these locations do not negatively impact growth or survival. The bulk sediment HQ evaluation predicts widespread and potentially severe toxicity throughout the Upper Lake and marsh area. However, the bulk sediment toxicity values utilized in this evaluation do not account for site-specific factors that may affect the bioavailability, and hence the toxicity, of metals in sediment. In addition, the risk conclusions based on the bulk sediment HQ evaluation are not supported by the sediment porewater HQ evaluation or the site sediment toxicity tests. The observation of several different benthic taxa in invertebrate community samples from the Upper Lake and marsh area suggests that sediments in these exposure areas provide suitable habitat for several species of invertebrates. However, it is not possible to assess if the invertebrate community present in on-site locations is adversely impacted because a suitable reference area is not available. Aquatic invertebrate tissue concentrations from the Upper Lake appeared to be higher than the off-site reference; however, the uncertainties associated with the tissue burden toxicity benchmarks make it difficult to conclude if these elevated tissue burdens were above a level of concern.

Based on these lines of evidence, it is concluded that the risk of population-level effects to benthic invertebrates in Upper Lake and the marsh area is relatively low. Because multiple lines of evidence support this conclusion, confidence in this conclusion is moderate to high.

5.9.3 Prickly Pear Creek

Fish

Four lines of evidence are available to assess potential risks to fish from Prickly Pear Creek. Based the surface water HQ evaluation, it is concluded that metals in surface water are not likely to adversely impact fish populations in Prickly Pear Creek. The screening-level evaluation of fish exposure from ingestion pathways also indicates that metals in prey items and sediment are below a level of concern. In addition, tissue burden comparisons suggests that tissue levels in fish caught downstream of the East Helena site are similar to levels upstream of the site. Although fish tissue concentrations are higher than tissue burden toxicity benchmarks, it is difficult to determine if tissue burdens are above a level of concern because of the uncertainties associated with the tissue burden toxicity benchmarks (i.e., reference samples also exceed benchmarks).

Based on these lines of evidence, it is concluded that the risk of population-level effects to fish in Prickly Pear Creek is minimal. Although multiple lines of evidence are available, risk estimates are based on limited exposure and toxicity datasets, so confidence in this conclusion is only moderate.

Benthic Invertebrates

Five lines of evidence are available to assess potential risks to benthic invertebrates from Prickly Pear Creek. Based on the surface water HQ evaluation and comparison to species-specific aqueous toxicity values, it is concluded that metals in surface water are probably not causing adverse effects in benthic invertebrate populations. The bulk sediment HQ evaluation predicted widespread toxicity due to several metals in Prickly Pear Creek, with the highest risks occurring at stations immediately downstream of the site. However, the bulk sediment toxicity values utilized in this evaluation may tend to over predict risks. The conclusions of widespread and severe toxicity from the bulk sediment evaluation are not supported by the sediment porewater HQ evaluation which indicates that risks for most metals are below a level of concern or are similar to the upstream reference area. A comparison of sediment porewater concentrations to invertebrate-specific aqueous toxicity values indicates that, while some more sensitive species may be impacted by metals, benthic invertebrate populations are not likely to be adversely impacted. The benthic macroinvertebrate community assessment suggests that Prickly Pear Creek stations downstream of the East Helena site may have decreased numbers of total and sensitive taxa compared to upstream areas. However, these community data are limited and did not provide firm evidence that the differences between reference and site areas are due to the presence of site-related metals. Based on a comparison of the community metric to measured environmental data, it is concluded that other non-metal factors are likely to be more important to community health than metals. While there is evidence that certain aquatic invertebrates (e.g., stonefly larvae) collected from below the East Helena site may have elevated tissue levels relative to upstream locations, it is not possible to determine if these levels are associated with predicted risks due to the uncertainty in the tissue-burden toxicity benchmarks(i.e., reference samples also exceed benchmarks).

Based on these lines of evidence, it is concluded that the risk of population-level effects to benthic invertebrates in Prickly Pear Creek is minimal to low. While multiple lines of evidence tended to support this conclusion, not all lines of evidence were entirely consistent with each other; therefore, confidence in this conclusion is moderate.

5.9.4 Overall

The table below provides an overall summary of the risk conclusions and confidence estimates for fish and benthic invertebrate receptors for each aquatic exposure area at the East Helena site.

Overall Weight of Evidence Summary for Aquatic Receptors				
Exposure Area	**Fish**		**Benthic Invertebrates**	
	Risk Conclusion	**Confidence**	**Risk Conclusion**	**Confidence**
Lower Lake	moderately high	low to moderate	high	high
Upper Lake	minimal to low	moderate	low	moderate to high
Prickly Pear Creek	minimal	moderate	minimal to low	moderate

6 RISK ASSESSMENT FOR WILDLIFE RECEPTORS

As shown in the ecological site conceptual model (Figure 4-1), wildlife receptors may be exposed to site-related contamination via several exposure pathways including ingestion of contaminated surface water while drinking, incidental ingestion of contaminated soil or sediment while feeding, and ingestion of contaminated food items. As described previously, wildlife receptors may be exposed to site-related contamination in several exposure areas, including the off-site upland areas in the surrounding Helena Valley, the on-site lakes and marsh area, and the riparian areas surrounding Prickly Pear Creek.

6.1 Evaluation of Risks in Off-Site Upland Areas

Previously, the CEA used measured soil and plant tissue concentrations from samples collected across the Helena Valley to evaluate risks to livestock. However, this assessment did not include an evaluation of potential risks to smaller mammals and birds.

An HQ approach was initially considered to address this data gap. However, the results of other mining-related ecological risk assessments often indicate that the receptors in upland areas with the highest exposures tend to be insectivorous rather than herbivorous wildlife. Terrestrial and soil invertebrate tissue concentrations have not been measured in the upland areas surrounding the East Helena site. While HQs for insectivorous wildlife could be estimated using default bioaccumulation factors for the uptake of metals from soil into invertebrate tissues, these uptake factors have been demonstrated at other mining-related sites to overestimate levels of metals in invertebrate tissues.

One way to avoid the assumptions and uncertainties associated with the estimation of dietary exposures would be to perform a wildlife biomonitoring study that directly measures receptor endpoints related to exposure and toxicity. Although wildlife biomonitoring has not been conducted at the East Helena site, a multi-year biomonitoring assessment has been conducted for the Anaconda Smelter site in Deer Lodge County, Montana (TTU, 2002). The Anaconda Smelter site is similar to the East Helena site with regard to the primary source materials, the mechanisms of exposure, and potential contaminants of concern. The primary objective of the Anaconda Smelter biomonitoring project was to quantify exposure to arsenic, cadmium, copper, lead, and zinc and the resultant effects in mammals and birds inhabiting the Anaconda Smelter (TTU, 2002).

Detailed information about the Anaconda Smelter Biomonitoring study design and measured exposure and effects data are provided in TTU (2002). In brief, this study was conducted from the spring of 1999 through the fall of 2000. Small mammals were captured from sites with varying levels of metals contamination, and tissue concentrations and health effect endpoints were measured to assess differences in small mammal exposure and toxicity between sites. In addition, American kestrels, European starlings, mountain bluebirds, tree swallows, and black capped chickadees were studied using nestboxes placed at sites with varying levels of metals contamination. Concentrations of metals in eggs, nestlings, and food items (obtained via nestling esophageal constriction) were analyzed and compared to nestbox reproductive endpoints.

Based on the results of the Anaconda Smelter wildlife biomonitoring evaluation, it was concluded that the primary receptors of concern were insectivorous passerine species and the primary contaminant of concern was lead (Hoff, 2002). In addition, the Anaconda assessment determined that lead began accumulating in prey items and passerine tissues at levels of concern when bulk soil lead concentrations were above about 650 mg/kg (Hoff, 2002).

Figure 6-1 provides a map of the concentration of lead in upland soils (CH2MHill, 1987). Note that in this figure the geometric mean isolines are shown on a $\log_{10}$ scale. Thus, a soil value of 650 mg/kg lead is equivalent to a value of 2.81 on a $\log_{10}$ scale. As seen in Figure 6-1, soil lead concentrations generally do not exceed 650 mg/kg for areas beyond a one mile radius of the smelter site. Elevated lead levels in soil spatially extend further east of the site (about one mile) compared to west of the site (about ¼ to ½ mile). This is probably because prevailing winds from the west (CH2MHill, 1987) carried smelter emissions east of the site.

Assuming that the exposure and toxicity at the East Helena site are similar to the Anaconda Smelter site, it appears that passerine insectivores may be adversely impacted in areas close to the smelter where soil lead concentrations exceed 650 mg/kg. However, it is important to note that lead toxicity may depend upon the chemical form of contamination. If the form of lead contamination at the East Helena site is different from that at the Anaconda Smelter site, a lead concentration in soil that is protective of accumulation and toxicity at the East Helena site may be different from that identified at the Anaconda Smelter site.

6.2 Evaluation of Risks in On-Site Lakes/Marsh and Riparian Areas

Birds and mammals may also be exposed to site-related contamination at the on-site lakes and marsh areas as well as in the riparian areas of Prickly Pear Creek. The East Helena on-site lakes and marsh area provide attractive habitat for aquatic and semi-aquatic wildlife. Based on sightings recorded in the Montana Bird Distribution Database[3], a variety of bird species utilize these on-site lakes and marsh areas, including the great blue heron, great egret, sandhill crane, belted kingfisher, mallard, osprey, double-crested cormorant, barn swallow and red-winged blackbird. Semi-aquatic mammals that may inhabit the on-site lakes and riparian areas include beaver, mink, and muskrat (Hunter/ESE, 1989).

Bird and mammal exposures at the on-site lakes and marsh areas and the riparian areas of Prickly Pear Creek were not evaluated previously as part of the CEA. Exposure of wildlife receptors may occur through ingestion of surface water while drinking, incidental ingestion of sediment while feeding, and ingestion of aquatic food chain items.

6.2.1 Approach

The 2003 ecological field investigation measured metal concentrations in surface water, sediment, and aquatic food item tissues for the purposes of evaluating potential risks to wildlife

[3] This project is a joint effort among the Montana Natural Heritage Program, Montana Audubon, and the Montana Department of Fish, Wildlife, and Parks. This database can be accessed online at: http://nhp.nris.state.mt.us/mbd/default.asp

from ingestion of contaminated media. Because these measured data were available, an HQ approach was used to evaluate wildlife exposures in these areas.

The basic equation used for calculation of an HQ value for exposure of a wildlife receptor to a chemical by ingestion of an environmental medium is:

$$HQi,j,r = \frac{Ci,j \times (IRj,r / BWr) \times DFj,r}{TRVi,r}$$

where:

$HQ_{i,j,r}$	=	HQ for exposure of receptor "r" to chemical "i" in medium "j"
$C_{i,j}$	=	Concentration of chemical "i" in medium "j" (e.g., mg/kg wet weight)
$IR_{j,r}$	=	Intake rate of medium "j" by receptor "r" (e.g., kg wet weight/day)
BW_r	=	Body weight of receptor "r" (kg)
$DF_{j,r}$	=	Dietary fraction of medium "j" by receptor "r" derived from site
$TRV_{i,r}$	=	Oral toxicity reference value for chemical "i" for receptor "r" (mg/kg BW/day)

Because all wildlife receptors are exposed to more than one environmental medium, the total Hazard Quotient (Total HQ) to a receptor from a specific chemical is calculated as the sum of HQs across all media:

$$Total\ HQi,r = \sum HQi,j,r$$

If the Total HQ is less than or equal to one, risk of unacceptable adverse effects in the exposed organisms is judged to be acceptable. If the Total HQ exceeds one, the risk of adverse effect in the exposed organisms is of potential concern.

6.2.2 Exposure Assessment

Surrogate Wildlife Receptors

It is not feasible to evaluate exposures and risks for every bird and mammal species potentially present at the East Helena Smelter site. For this reason, several species were selected to serve as representative species (surrogates) of several different feeding guilds. The feeding guilds and ingestion exposure pathways of interest include:

Receptor Type	Exposure Pathways	Selected Surrogate
Waterfowl	surface water, sediment, aquatic plants and invertebrates	Mallard duck
Piscivorous bird	surface water, sediment, fish	Belted kingfisher
Piscivorous mammal	surface water, sediment, fish	Mink
Insectivorous bird	surface water, sediment, aquatic invertebrates	Cliff Swallow

Wildlife Exposure Factors

Exposure parameters and dietary intake factors for each surrogate wildlife receptor were derived from the Wildlife Exposure Factors Handbook (USEPA, 1993), as well as a variety of other sources. Wildlife exposure factors were selected to represent average year-round adult exposures. When possible, exposure information was limited to receptor data from Montana or a representative western state. In some cases, no quantitative data could be located, so professional judgment was used in selecting exposure parameters. The dietary fraction (DF) estimates were based on the average across all seasons. In this assessment, it was assumed that all of the receptor home range was located within the East Helena site and 100% of the total dietary intake came from the site.

The exposure parameters selected for each representative wildlife receptor are detailed in Appendix E and summarized in Table 6-1.

Exposure Point Concentrations (EPCs)

For the purposes of estimating risks to wildlife receptors, there are three potential on-site exposure areas at the East Helena site – Lower Lake, Upper Lake and Marsh Area, and Prickly Pear Creek. In addition, exposure estimates were also calculated for Canyon Ferry Reservoir, an off-site reference location, and for a station along Prickly Pear Creek located upstream of the site, for the purposes of comparison with site exposures.

The 2003 ecological field investigation provided measured concentration data for 23 inorganics in surface water (total fraction) and bulk sediment at several stations within each exposure area. In addition, concentrations of arsenic, cadmium, copper, lead, selenium, mercury[4], and zinc were measured in aquatic plants/algae, benthic invertebrates, and fish from the Upper Lake and marsh area. While the 2003 investigation did not collect aquatic food items from Prickly Pear Creek, USFWS (1997) provides measured concentrations of arsenic, cadmium, copper, lead, selenium, mercury[4], and zinc for benthic invertebrates and fish in Prickly Pear Creek above and below the East Helena site. Because USFWS (1997) does not provide measured data for aquatic plants in Prickly Pear Creek, concentrations in aquatic plants were assumed to be equal to those measured in benthic invertebrates. Based on a comparison of measured aquatic plant and aquatic invertebrate data from the Upper Lake (see Appendix A), this assumption is likely to be appropriate for most metals with the exception of arsenic. For arsenic, it appears that concentrations in aquatic plants range from 2 to 10 times higher than in aquatic invertebrates. Therefore, arsenic concentrations in aquatic plants were assumed to be 10 times higher than measured aquatic invertebrate tissue concentrations for Prickly Pear Creek. No information was located which provided measured concentrations for aquatic food items from Lower Lake.

Wildlife receptors are likely to move at random across an exposure area. Therefore, exposure is best characterized as the mean concentration across the entire area. Because only a limited number of samples are available to represent the exposure area, there is uncertainty associated with this calculated mean concentration. To account for this uncertainty, the USEPA recommends using an exposure point concentration (EPC) to represent the typical exposures at a

[4] Mercury was only analyzed in fish tissue (see Appendix A).

location. The EPC is either the 95% Upper Confidence Level (95UCL) on the mean concentration or the maximum concentration, whichever is lower. For datasets with a limited number of samples, the 95UCL on the mean is often higher than the maximum. At this site, the number of samples from each exposure area for this site was relatively small. Therefore, wildlife exposures were simply based on the maximum detected concentrations.

Table 6-2 provides a summary of the maximum detected values for surface water, sediment, and aquatic food items used to calculate HQs for wildlife within each exposure area. Appendix A provides a detailed summary of measured concentrations in each exposure media.

6.2.3 Toxicity Assessment

<u>Wildlife Toxicity Reference Values</u>

A Toxicity Reference Value (TRV) for wildlife provides an estimate of the dose (in units of mg of chemical per kg of body weight per day, mg/kg/day) associated with a known effect. Often, two types of dose-based TRVs are identified. The first TRV is an estimate of the dose that is not associated with any adverse effects, and is referred to as the no observed adverse effect level (NOAEL) TRV. The second TRV is an estimation of the dose that causes an observable adverse effect, and is referred to as the lowest observed adverse effect level (LOAEL) TRV. The true threshold for adverse effects lies between the NOAEL and LOAEL TRVs.

It is expected that the adverse effect threshold will vary from species to species within any particular taxonomic group. If data are available for the effects thresholds for many different species in a particular group, the data may be rank-ordered to define a species-sensitivity distribution (SSD) for that group. In order to ensure that the HQs calculated for each representative species are protective of most species within the group, a TRV which represents the lower end of the SSD is preferred. Ideally, toxicity data would be sufficient to define the SSD and support derivation of a TRV for each unique feeding guild selected for evaluation (e.g., avian omnivores, mammalian herbivores, etc.). Unfortunately, available toxicity data for birds and mammals are generally not robust enough to develop SSDs for each feeding guild, so a single bird TRV and mammal TRV were used to represent all bird and mammal species, respectively. To the extent the data allow, each TRV was selected to represent the low end of the SSD for each group (birds, mammals).

Because the purpose of this assessment was to evaluate wildlife exposures from ingestion of contaminated media at the East Helena site over the lifetime of the receptor, TRVs were derived from studies in which the exposure route was oral (e.g., via ingestion in diet or water or via gavage), and dosing occurred over a long period of time (chronic exposure) or during a critical lifestage period. The wildlife TRVs were selected to represent relevant toxicity endpoints for population sustainability (e.g., growth, reproduction, mortality).

TRVs for wildlife were compiled from three secondary sources (shown in order of preference): USEPA (2003c), Engineering Field Activity West (1998), and Sample et al. (1996). Appendix B provides a summary of the TRV derivation approach and the bird and mammal TRVs selected by each secondary source. The TRVs provided in each of these sources are described briefly below.

In USEPA (2003c), a single bird TRV and mammal TRV was derived which represents the highest no effect level below the level which effects are first observed across multiple species and endpoints. Risk calculations in this assessment used this TRV without adjustment. In Engineering Field Activity West (1998) and Sample et al. (1996), two types of TRV are provided for both birds and mammals; a NOAEL TRV (or Low TRV in Engineering Field Activity West, 1998) and a LOAEL (or High TRV in Engineering Field Activity West, 1998). Risk calculations in this assessment were based on the selected NOAEL (or Low TRV). Table 6-3 summarizes the mammal and bird TRVs that were used to evaluate potential risks to representative wildlife species.

Relative Bioavailability

TRVs from literature studies are generally expressed in units of ingested dose (mg/kg BW/day). However, the toxicity of an ingested dose depends on how much of the ingested dose is actually absorbed, which in turn depends on the properties of both the chemical and the exposure medium. Ideally, toxicity studies would be available that establish empiric TRVs for all site media of concern (water, food, soil, sediment). However, most laboratory tests use either food or water as the exposure medium, and essentially no studies use soil or sediment. Therefore, in cases where a TRV is based on a study in which the oral absorption fraction is different that what would be expected for a site medium, it is desirable to adjust the TRV to account for the difference in absorption whenever data permit.

The ratio of absorption from the study medium compared to absorption from site medium is referred to as the relative bioavailability (RBA). The RBA is used to adjust the TRV as follows:

TRV(adjusted) = TRV(literature) / RBA

For the purposes of this assessment, the RBA for all chemicals in all site media was assumed to be equal to 1.0 (100%). This approach is likely to be realistic for contaminants in water and most food items, but may tend to overestimate exposure and risk from ingestion of sediment. However, no site-specific information on RBA was available which would provide a basis to modify this assumption.

6.2.4 Risk Characterization

Summary of Total HQs

Appendix F (one table per surrogate wildlife receptor) provides the detailed HQ values for each chemical for each exposure pathway and across all exposure pathways within each exposure area. Tables 6-4 to 6-7 provide a summary of the total estimated risks (Total HQs) for each receptor by chemical. In these tables, HQ values greater than one are shown to two significant figures, and all values greater than one are shaded. In addition, these tables identify which pathways were able to be evaluated quantitatively based on measured data and were included in the Total HQ. It is important to note that for those chemicals (i.e., antimony, cobalt, etc.) and lead, copper, zinc, and cadmium in benthic invertebrates and fish and manganese in sediment. The highest predicted risks for avian receptors were due to lead in aquatic food items.

6.3 Conclusions for Wildlife Receptors

6.3.1 Off-Site Upland Areas

While quantitative HQs were not calculated for birds and mammals in off-site upland areas, potential risks were evaluated using extensive information on wildlife exposure and toxicity due to smelter-related releases at the Anaconda Smelter site (TTU, 2002). This study concluded that insectivorous passerine species were the most sensitive wildlife receptor to smelter-related soil contamination, and the primary contaminant of concern was lead. Using the soil lead threshold of 650 mg/kg established for the Anaconda Smelter, it appears that passerine insectivores may be adversely impacted in upland areas within one mile of the East Helena Smelter site due to elevated soil lead concentrations.

Although there is only this single line of evidence available to support this conclusion, there is moderately high confidence in this conclusion for several reasons. First, the Anaconda Smelter site is also located in Montana, and the contaminants (metals from mining activities) and exposure mechanisms (smelter emissions) are similar to those for the East Helena site. In addition, the Anaconda assessment was a multi-year study conducted in accord with a detailed sampling plan which yielded an extensive database of biomonitoring endpoints for several types of wildlife species. Finally, conclusions based on direct community observations are not limited by the numerous assumptions and estimates needed to quantify exposure and toxicity for the purposes of estimating HQs. Therefore, biomonitoring results are thought to provide a more accurate assessment of site-specific conditions.

6.3.2 On-Site Lakes/Marsh and Riparian Areas

Only one line of evidence (HQ calculations) is available to evaluate risks to wildlife from the on-site lakes and marsh area and the riparian areas along Prickly Pear Creek. Based on the HQ estimates for wildlife, the following conclusions are drawn:

- Ingestion of metals in surface water from the on-site lakes and Prickly Pear Creek is not likely to adversely impact birds and mammals at the East Helena site.

- For the on-site lakes and marsh area, adverse effects may occur in insectivorous birds, waterfowl, and piscivorous birds and mammals due to the incidental ingestion of several metals in sediment. The metal of primary concern is lead with the highest estimated risks for insectivorous birds exposed at the Lower Lake. The metals of chief potential concern from aquatic food chain exposures (ingestion of fish, aquatic plants, and aquatic invertebrates) in these areas include lead, copper, cadmium, and zinc.

- For Prickly Pear Creek, piscivorous mammalian receptors are not likely to be adversely impacted due to ingestion of contaminated media. Adverse effects may occur in insectivorous birds, waterfowl, and piscivorous birds due to the ingestion of several exposure areas (i.e., Lower Lake) for which measured aquatic food items were not available, actual risks may be higher than predicted.

A comparison of estimated risks at on-site locations compared to the reference locations (Canyon Ferry Reservoir and upstream Prickly Pear Creek) helps identify cases where risks were above a level of concern not only at the site but also at the reference area. As discussed in Section 4.3.1, cases where a contaminant HQ exceeds one in reference areas indicates that on-site risks for that chemical should be interpreted cautiously. For example, zinc Total HQs for the belted kingfisher (Table 6-5) were similar for upstream and downstream (HQs of 1.7) Prickly Pear Creek which suggests that elevated levels of zinc on-site are not likely to be due to site-related activities.

It is important to remember that the HQ values presented in Tables 6-4 to 6-7 were calculated using NOAEL TRVs. Therefore, an HQ value above one does not necessarily mean that adverse effects are expected to occur. Whether an adverse effect will occur that results in a population-level impact depends upon the magnitude of the HQ exceedance, how close the NOAEL TRV is to the effects threshold, and the type of effect.

In addition, HQ values are based on TRVs that take inter-species variability in sensitivity into account and are intended to be protective of nearly all species within the receptor class or feeding guild evaluated. Because of this, when the calculated HQ for a feeding guild is found to exceed one, it is not necessarily true that all species comprising the guild will be at risk. Rather, an HQ above one implies that the most sensitive species in the guild could be at risk, but risks may or may not extend to other less sensitive species in the guild. Therefore, these risks for wildlife should be interpreted as conservative estimates.

Identification of Primary Risk Drivers

For each receptor, the exposure pathways that contribute the most to predicted risks will depend upon the chemical and the exposure area. Table 6-8 provides a summary of the metals, exposure pathways, and exposure areas for which estimated risks were above a level of concern. As seen, estimated risks from ingestion of surface water were below a level of concern for all receptors at all exposure areas. For the dietary and sediment ingestion exposure pathways, contaminants consistently identified as metals of concern included lead, copper, cadmium, selenium, zinc, and arsenic.

For the on-site lakes and marsh area, the primary contributor to estimated risks for most metals was incidental ingestion of sediment. When ingestion of sediment was not the primary contributor, the metals in dietary items that contributed most to estimated risks were copper in fish and benthic invertebrates, and zinc and mercury in fish. The highest predicted risks for avian receptors were due to lead in sediment while the highest predicted risks for mammalian receptors were due to antimony in sediment.

For Prickly Pear Creek, the primary contributor to estimated risks for most metals was ingestion of aquatic food items. As seen, predicted risks for piscivorous mammals were below a level of concern for all metals for all exposure pathways. Estimated risks for birds were primarily due to metals in aquatic food items. The primary metals of concern include lead, copper, and zinc.

- In nearly all cases, estimated risks for the on-site lakes and marsh area were higher than those calculated for Prickly Pear Creek. In addition, avian receptors tended to have higher predicted risks than mammalian receptors, and insectivorous birds tended to have higher predicted risks compared to omnivorous and piscivorous birds.

Because no other lines of evidence are available to support these risk conclusions and risk estimates are based on a limited dataset, there is low confidence in these conclusions. In order to better assess the accuracy of these risk predictions, other lines of evidence, such as site-specific toxicity assessments, community surveys, and/or wildlife biomonitoring studies would be needed.

7 UNCERTAINTIES

Quantitative evaluation of ecological risks is limited by uncertainty regarding a number of important data. This lack of knowledge is usually circumvented by making estimates based on whatever limited data are available, or by making assumptions based on professional judgment when no reliable data are available. Because of these assumptions and estimates, the results of the risk calculations are themselves uncertain, and it is important for risk managers and the public to keep this in mind when interpreting the results of a risk assessment.

7.1 Uncertainties in Nature and Extent of Contamination

7.1.1 Representativeness of Samples Collected

Concentration levels of chemicals in environmental media are often quite variable as a function of location, and may also vary significantly as a function of time. Thus, samples collected during a field sampling program may or may not fully characterize the spatial and temporal variability in actual concentration levels. At this site, field samples were collected in accord with sampling and analysis plans that specifically sought to ensure that samples were spatially representative of the range of conditions across each exposure area. However, the number of samples collected was relatively small and encompassed only a single sampling event. Thus, without the collection of a greater number of samples over both space and time, some uncertainty remains as to whether the samples collected provide an accurate representation of the distribution of concentration values actually present.

7.1.2 Accuracy of Analytical Measurements

Laboratory analysis of environmental samples is subject to a number of technical difficulties, and values reported by the laboratory may not always be exactly correct. The magnitude of analytical error is usually small compared to other sources of uncertainty, although the relative uncertainty increases for results that are near the detection limit.

7.2 Uncertainties in Exposure Assessment

7.2.1 Pathways Not Evaluated

Exposure pathways selected for quantitative evaluation in this assessment do not include all potential exposure pathways for all ecological receptors. Exposure pathways that were not evaluated include:

- Ingestion of sediments and prey items by fish[5]
- Ingestion of sediments and prey items by benthic invertebrates
- Dermal exposures of wildlife to soil, sediment and surface water
- Inhalation of dust particles by wildlife

[5] Only a subset of metals (arsenic, cadmium, copper, lead, zinc) could be evaluated quantitatively.

- Ingestion of aquatic food items from Lower Lake by wildlife
- Exposures by amphibians and reptiles

Omission of these pathways will tend to lead to an underestimation of total risk to the exposed receptors. As discussed previously in Section 4, many of these exposure pathways (i.e., dermal exposures of wildlife) are likely to be minor compared to other pathways that were evaluated, and the magnitude of the underestimation is not likely to be significant in most cases. However, the exclusion of some exposure pathways may tend to underestimate predicted risks in some cases.

For Lower Lake, the exclusion of wildlife exposures via ingestion of food items may lead to an underestimation of predicted risks for birds and mammals that preferentially feed from this exposure area. In addition, risks to amphibians and reptiles were not evaluated quantitatively in this assessment. The comparability of predicted risks for aquatic receptors and wildlife to those expected for amphibian and reptilian receptors is uncertain.

7.2.2 Chemicals Not Detected

In both the aquatic and wildlife receptor evaluations, any chemical that was not detected in a site medium was not included in the HQ evaluation. Omission of these chemicals is likely to result in an underestimation of risk. However, it is assumed that the magnitude of the underestimation is likely to be low in most cases. This is because the analytical detection limit was below the applicable toxicity benchmark in most cases. In some instances, the analytical detection limit was too high to determine if the chemical was present above a level of concern (i.e., exposure concentrations and doses based on the detection limit were higher than the toxicity benchmark). Table 7-1 (Panel A) identifies chemicals for which the detection limits were inadequate to assess potential risk. It is assumed that while the hazards from chemicals within this category are unknown, they are probably not large enough to cause a substantial underestimation of risk.

7.2.3 Wildlife Exposure Factors

The intake (ingestion) rates for food, soil, and sediment used to estimate exposure of wildlife at the site are derived from literature reports of intake rates, body weights, dietary compositions, consumption rates, and metabolic rates in receptors at other locations or from measurements of laboratory-raised organisms. These values may or may not serve as appropriate models for site-specific intake rates of typical wild receptors at this site. Moreover, the actual dietary composition of an organism will vary daily and seasonally. In addition, some wildlife receptor-specific intake rates are estimated by extrapolation from data on a closely related species or by use of allometric scaling equations (scaling of intake rates based on body weights). This introduces further uncertainty into the exposure and risk estimates. These uncertainties could either under- or overestimate the actual exposures of wildlife to chemicals in water, sediment, and diet.

For this analysis, it was also assumed that wildlife exposures were continuous and that receptor home ranges were located entirely within the East Helena site exposure areas (i.e., the entire total dietary intake was from the site). In the case of resident receptors with small home ranges, this assumption is likely to be fairly realistic. However, this assumption may tend to overestimate exposures for receptors that have larger home ranges and/or migratory species that may not be exposed on-site most of the time.

7.3 Uncertainties in Toxicity Assessment

7.3.1 Representativeness of Receptors Evaluated

Risk characterizations for aquatic receptors were based on toxicity values which included a generalized set of species found in freshwater aquatic communities. However, not all of these species are expected to occur in waters of the East Helena site. Thus, HQ values above one may reflect risks to species that are absent at the site, and risks to species that are actually present at the site may be lower.

Risks to wildlife were assessed for a selected subset of species which were representative of several feeding guilds likely to be present at the East Helena site. Although the representative wildlife receptors selected represent a range of taxonomic groups, these species may not represent the full range of sensitivities present. The species selected may be either more or less sensitive to chemical exposure than typical species located within the area.

7.3.2 Absorption from Ingested Doses

The toxicity of an ingested chemical depends on how much of the chemical is absorbed from the gastrointestinal tract into the body. However, the actual extent of chemical absorption from ingested media (soil, sediment, food, and water) is usually not known. The hazard from an ingested dose is estimated by comparing the dose to an ingested dose that is believed to be safe, based on tests in a laboratory setting. Thus, if the absorption is the same in the laboratory test and the exposure in the field, then the prediction of hazard will be accurate. However, if the absorption of a chemical from the site medium is different (usually lower) than what occurred in the laboratory study, then the hazard estimate will be incorrect (usually too high).

In this assessment, estimates of wildlife exposure assumed a relative bioavailability (RBA) of 100% for all chemicals in all media. This assumption is expected to be reasonable for chemicals in surface water and most dietary food items, but may tend to overestimate exposure for chemicals in soil and sediment. This is because metals in soil and sediment may occur in mineral phases that have low solubility, and this tends to reduce the amount of metal that is absorbed when ingested. Metal bioavailability, especially for mining-related contamination, is likely to be lower than 100%, but there are no site-specific data which provide information on RBA for wildlife to refine the HQ calculations for sediment.

7.3.3 Absence of Toxicity Data for Some Chemicals

For a number of chemicals that were detected in one or more samples of site media, no reliable toxicity benchmark could be located for one or more receptor types. Table 7-1 (Panel B) provides a list of chemicals that were detected in site media but for which no toxicity benchmarks were available. The inability to evaluate hazards from these chemicals is expected to result in an underestimation of risk, but it is suspected that the magnitude of the error is usually likely to be low. This is because the absence of a toxicity benchmark for a chemical is most often because toxicological concern over that chemical is low. That is, chemicals that lack benchmarks are often considered to be relatively less hazardous that those for which benchmarks do exist. To the extent that this is true (even though there are likely some exceptions to this rule), risks from chemicals without toxicity benchmark values are likely not to contribute risks of the same magnitude as those predicted for chemicals that do have a toxicity benchmark value.

7.3.4 Extrapolation of Toxicity Data Across Dose or Duration

In some cases, TRV data are available only for high dose exposures and extrapolation to low doses (similar to those that actually occur at the site) is a source of uncertainty. Likewise, some TRVs are based on relatively short-term exposures, and extrapolation to long-term exposures is uncertain, especially for chemicals that tend to build up in the exposed organism. When such extrapolations are necessary, it is customary to include one or more "uncertainty factors" in the derivation of the benchmark to account for the extrapolation. In general, these uncertainty factors are likely to be somewhat too large, so the benchmarks derived in this way are more likely to overestimate than underestimate true risk.

7.3.5 Extrapolation of Toxicity Data from Laboratory to Field Conditions

Available toxicity data are usually generated under laboratory conditions, and extrapolation of those data to free-living receptors in the field is uncertain. One factor is that laboratory organisms are more homogeneous that wild populations. For example, laboratory test populations are usually all the same genetic strain, age, and gender, and all are usually healthy. In contrast, wild populations are genetically diverse, consist of individuals of different ages and genders, and health status may vary widely between individuals. In addition, laboratory animals are generally free from the stresses experienced by a wild population. Because of these factors, extrapolation of dose-response data and toxicity factors from laboratory species to wild populations is uncertain. The magnitude and direction of error introduced by this extrapolation is unknown. However, greater variability in response to a chemical toxicant in wild populations than laboratory species is expected to result in an underestimation of risk to individuals in a population that have higher than average levels of exposure.

7.4 Uncertainties in Risk Characterization

7.4.1 Interactions Among Chemicals

Most toxicity benchmark values are derived from studies of the adverse effects of a single contaminant. However, exposures to ecological receptors usually involve multiple contaminants, raising the possibility that synergistic or antagonistic interactions might occur. Data are generally not adequate to permit any quantitative adjustment in toxicity values or risk calculations based on inter-chemical interactions. In accordance with USEPA guidance, effects from different chemicals are not added unless reliable data are available to indicate that the two (or more) chemicals act on the same target tissue by the same mode of action. At this site, HQ values for each chemical were not added across different chemicals. If any of the chemicals of concern at the site act by a similar mode of action, total risks could be higher than estimated. Conversely, if the chemicals of concern at the site act antagonistically, total risks could be lower than estimated.

7.4.2 Estimation of Population-Level Impacts

Assessment endpoints for the receptors at this site are based on the sustainability of exposed populations, and risks to some individuals in a population may be acceptable if the population is expected to remain healthy and stable. However, even if it is possible to accurately characterize the distribution of risks or effects across the members of the exposed population, estimating the impact of those effects on the population is generally difficult and uncertain. The relationship between adverse effects on individuals and effects on the population is complex and depends on the demographic and life history characteristics of the receptor being considered as well as the nature, magnitude and frequency of the chemical stresses and associated adverse effects. Thus, the actual risks that will lead to population-level adverse effects will vary from receptor to receptor.

7.5 Summary of Uncertainties

Table 7-2 summarizes the various sources of uncertainty in this assessment, along with a qualitative estimate of the direction and magnitude of the likely errors attributable to the uncertainty. Based on all of these considerations, the HQ and Total HQ values calculated and presented in this assessment should be viewed as having substantial uncertainty. Because of the inherent conservatism in the derivation of many of the exposure estimates and toxicity benchmarks, HQ and Total HQ values presented in this assessment should generally be viewed as being more likely to be high than low, and results and conclusions should be interpreted accordingly.

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FIGURES

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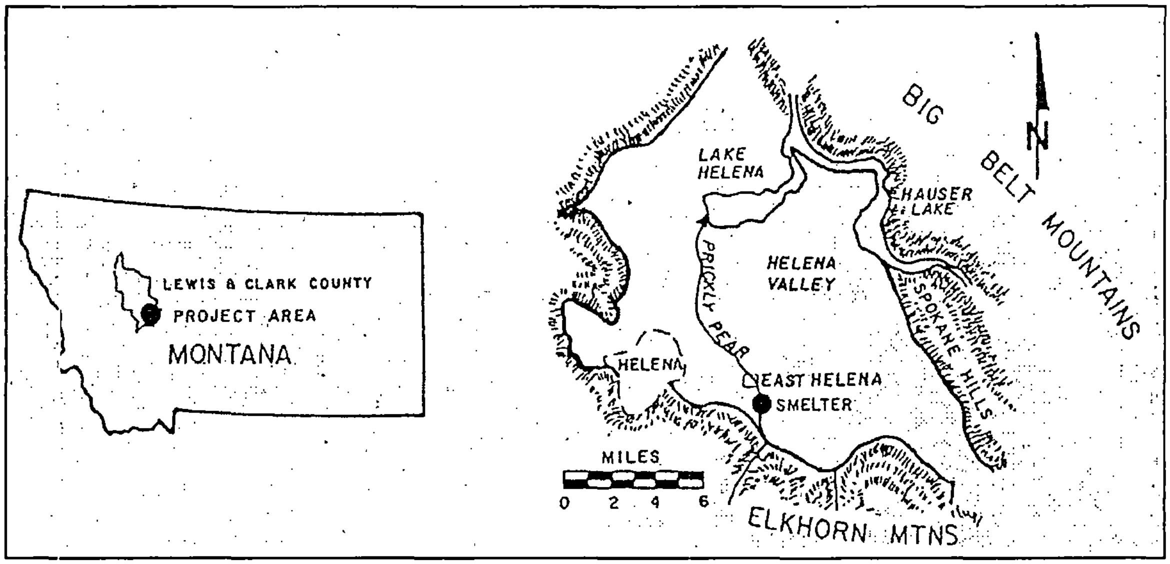
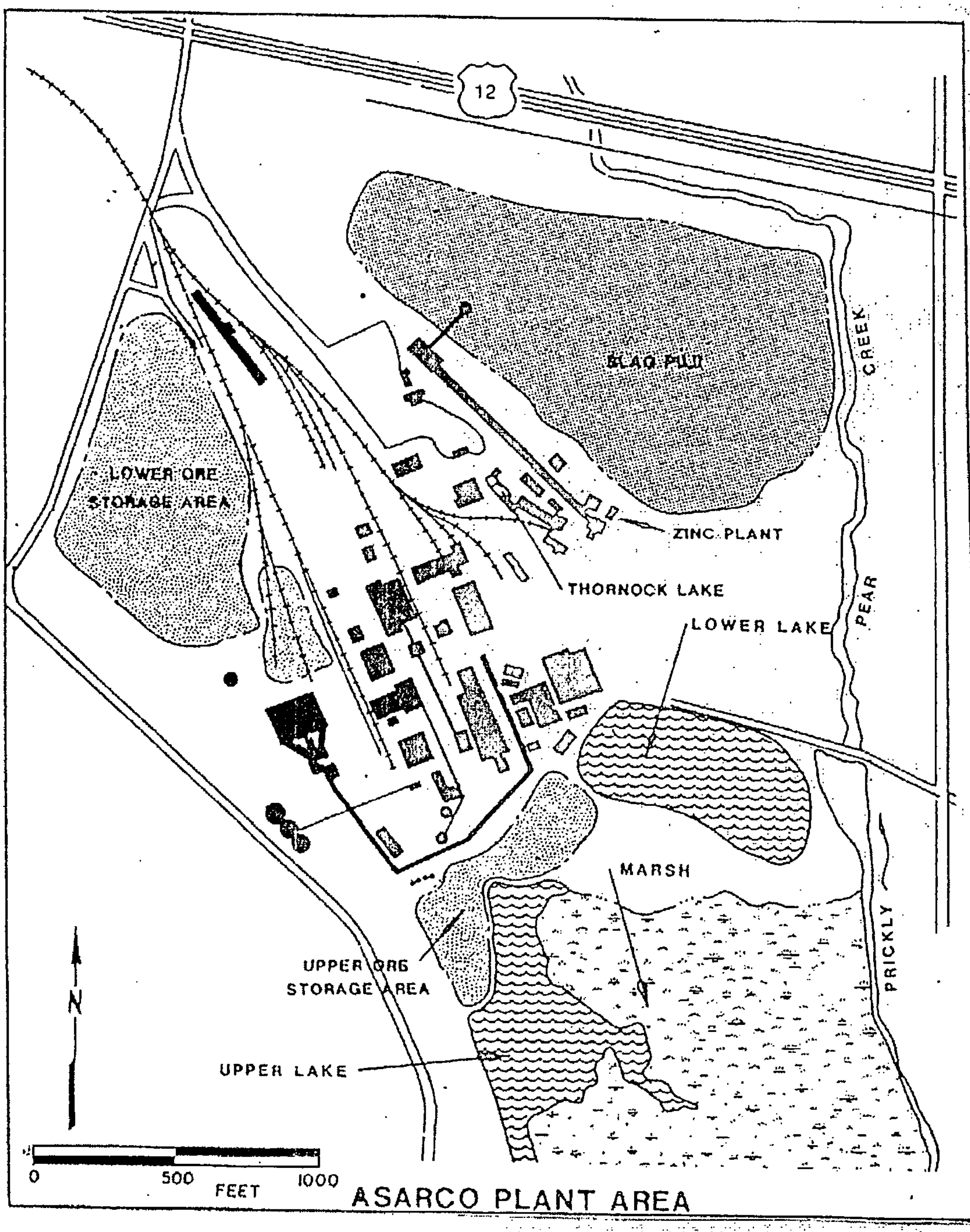
Figure 2-1
East Helena Site Location Map



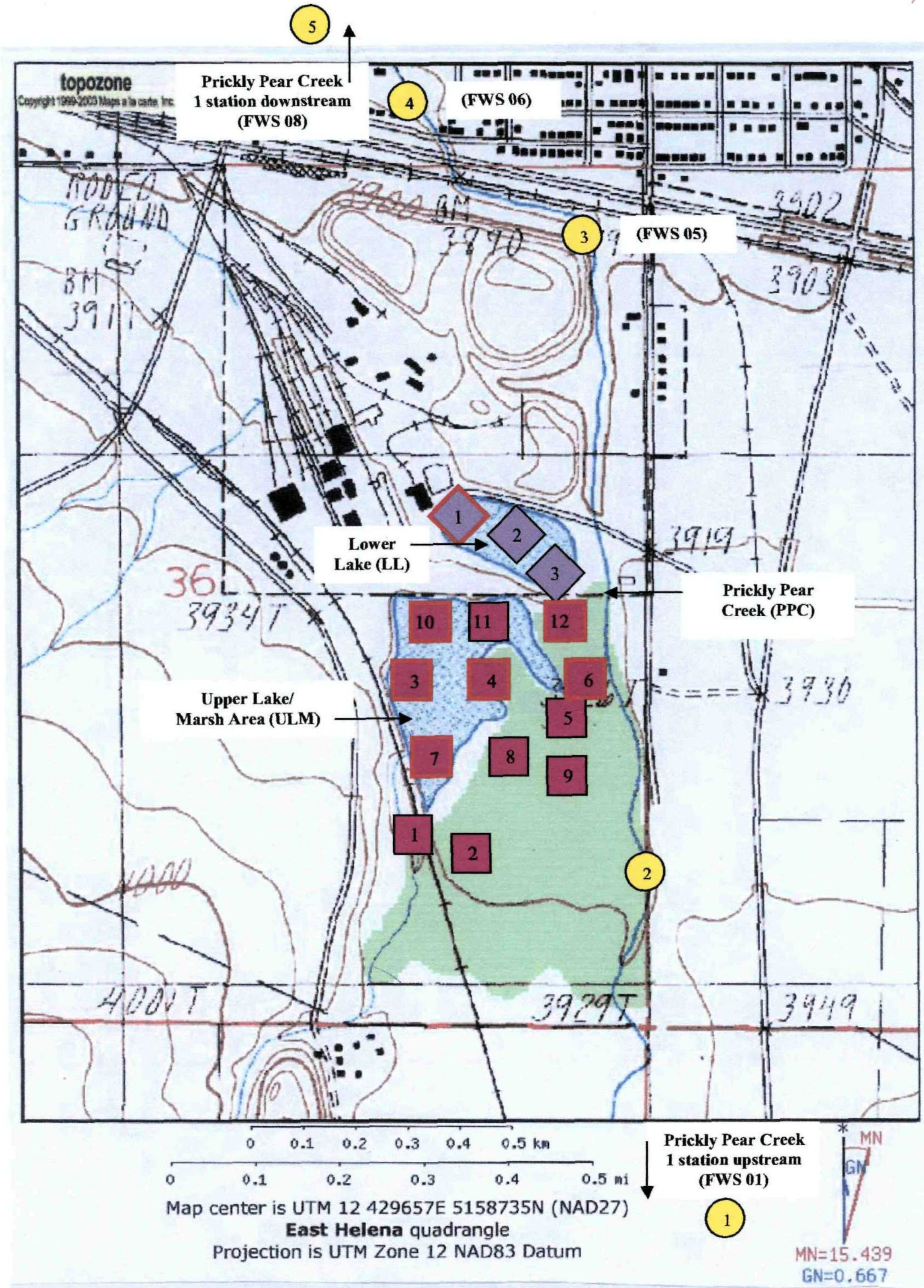
Source: Remedial Investigation (CH2MHill, 1987)

Figure 2-2
ASARCO Smelter Map



Source: Remedial Investigation (CH2MHill, 1987); aerial view circa 1984.

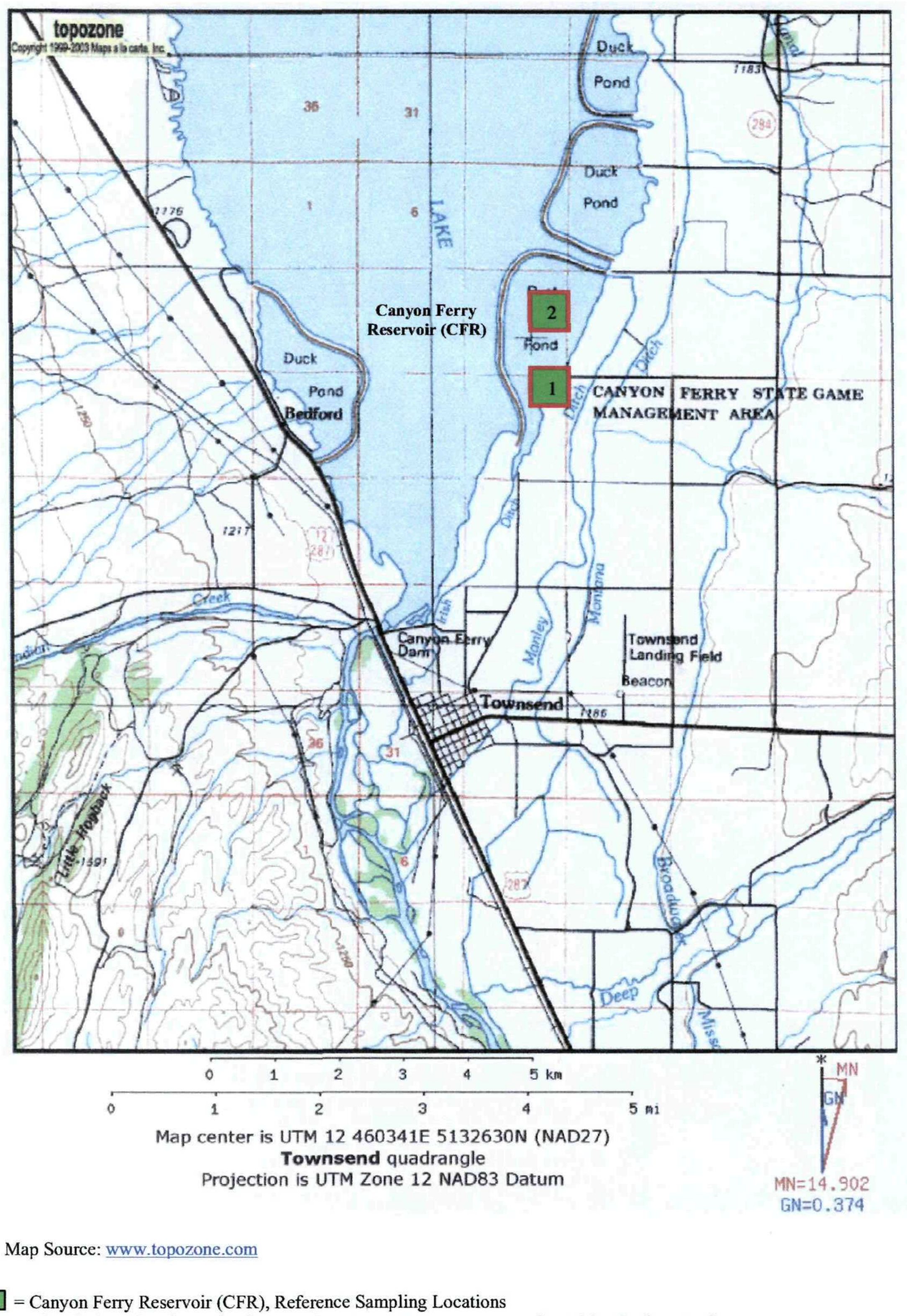
Figure 3-1 (Part A)
Sampling Locations for the Fall 2003 Ecological Field Investigation



Map Source: www.topozone.com
Prickly Pear Creek stations are also identified with their corresponding USFWS (1997) sampling location #

■ = Upper Lake/ Marsh Area (ULM) ◆ = Lower Lake (LL) ○ = Prickly Pear Creek (PPC)
[symbols outlined in red indicate sediment toxicity tests were conducted for this location]

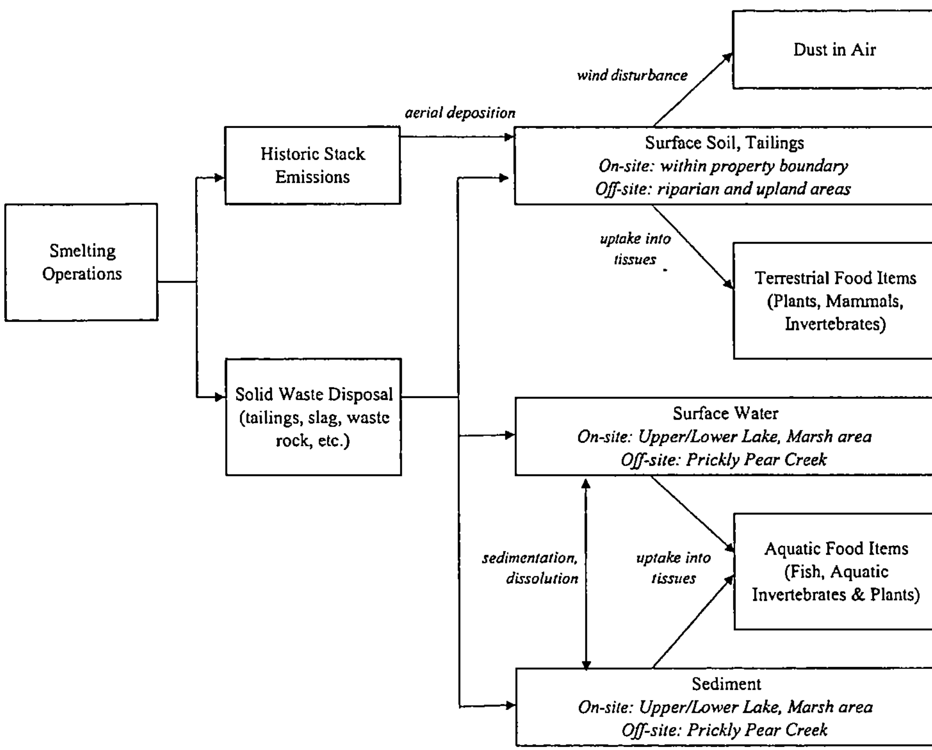
Figure 3-1 (Part B)
Sampling Locations for the Fall 2003 Ecological Field Investigation



Map Source: www.topozone.com

■ = Canyon Ferry Reservoir (CFR), Reference Sampling Locations
[symbols outlined in red indicate sediment toxicity tests were conducted for this location]

Figure 4-1
Site Conceptual Model for Ecological Exposure at the East Helena Smelter Site



Potentially Impacted Environmental Media	Exposure Route	Aquatic Receptors		Terrestrial Receptors (Plants & Invert.)		Wildlife Receptors (Birds & Mammals)		Livestock
		Fish	Benthic Organisms	Plants	Soil Organisms	Riparian	Upland	Upland
Dust in Air	Inhalation					X	X	X
	Direct Contact			X				
Surface Soil, Tailings	Ingestion						●	●
	Direct Contact			●	●		X	X
Terrestrial Food Items	Ingestion						●	●
Surface Water	Ingestion					●		●
	Direct Contact	●	●			X		X
Aquatic Food Items	Ingestion	●[a]	X			●		
Sediment	Ingestion	●[a]	X			●		
	Direct Contact	X	●			X		

LEGEND

- (blank) Pathway is not complete; no evaluation required
- X Pathway is complete, but is judged to be minor compared to other exposure pathways; qualitative evaluation
- O Pathway is complete and might be significant; but insufficient data are available for quantitative evaluation
- ● Pathway is complete and might be significant; sufficient data are available for quantitative evaluation

Footnotes:

[a] Can only be evaluated quantitatively for a subset of metals (arsenic, cadmium, copper, lead, and zinc).

Figure 4-2
Conceptual Approach for Characterizing Population-Level Risks

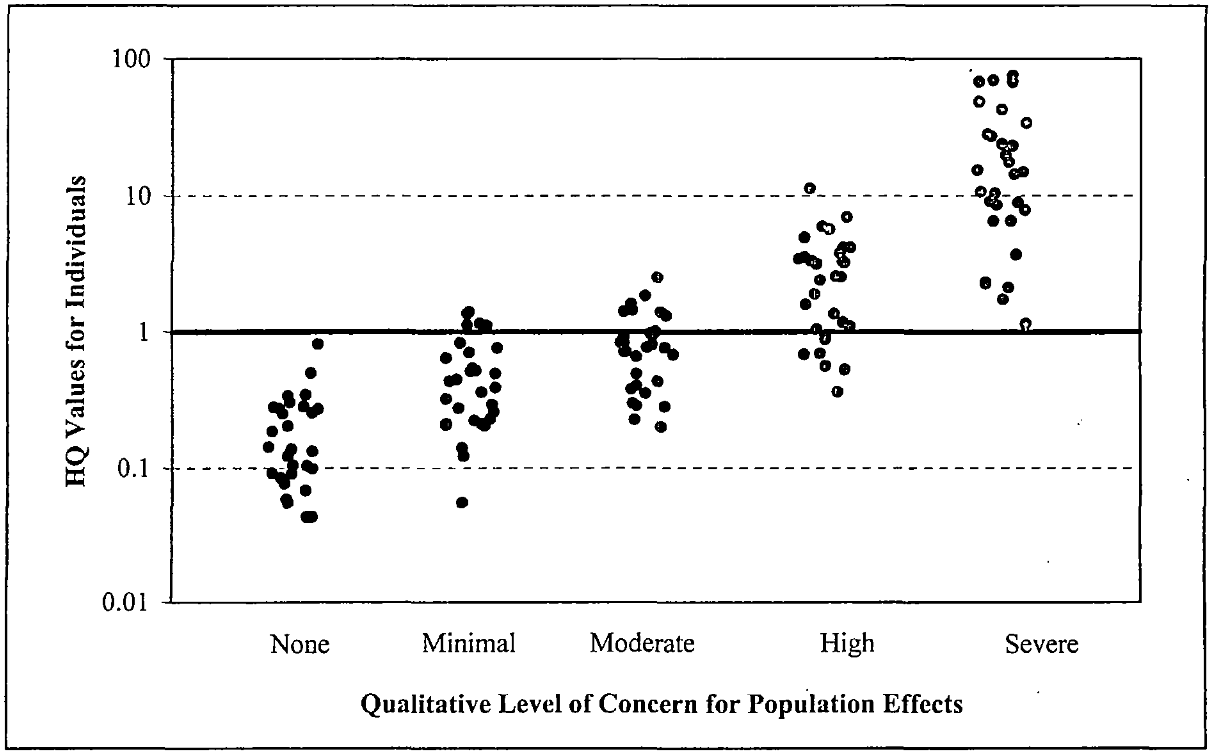
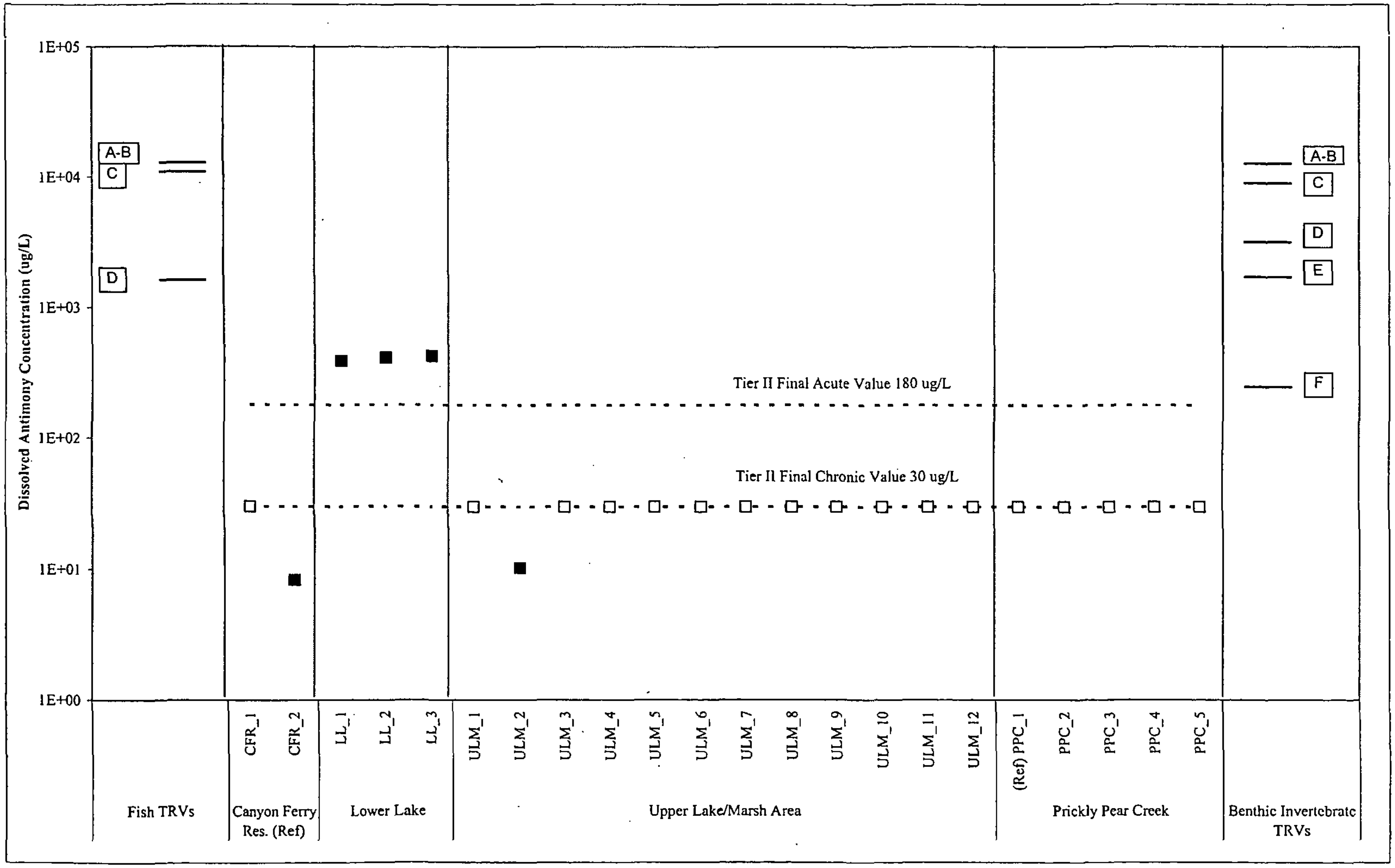


Figure 5-1a

Comparison of Antimony Concentrations in Surface Water with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



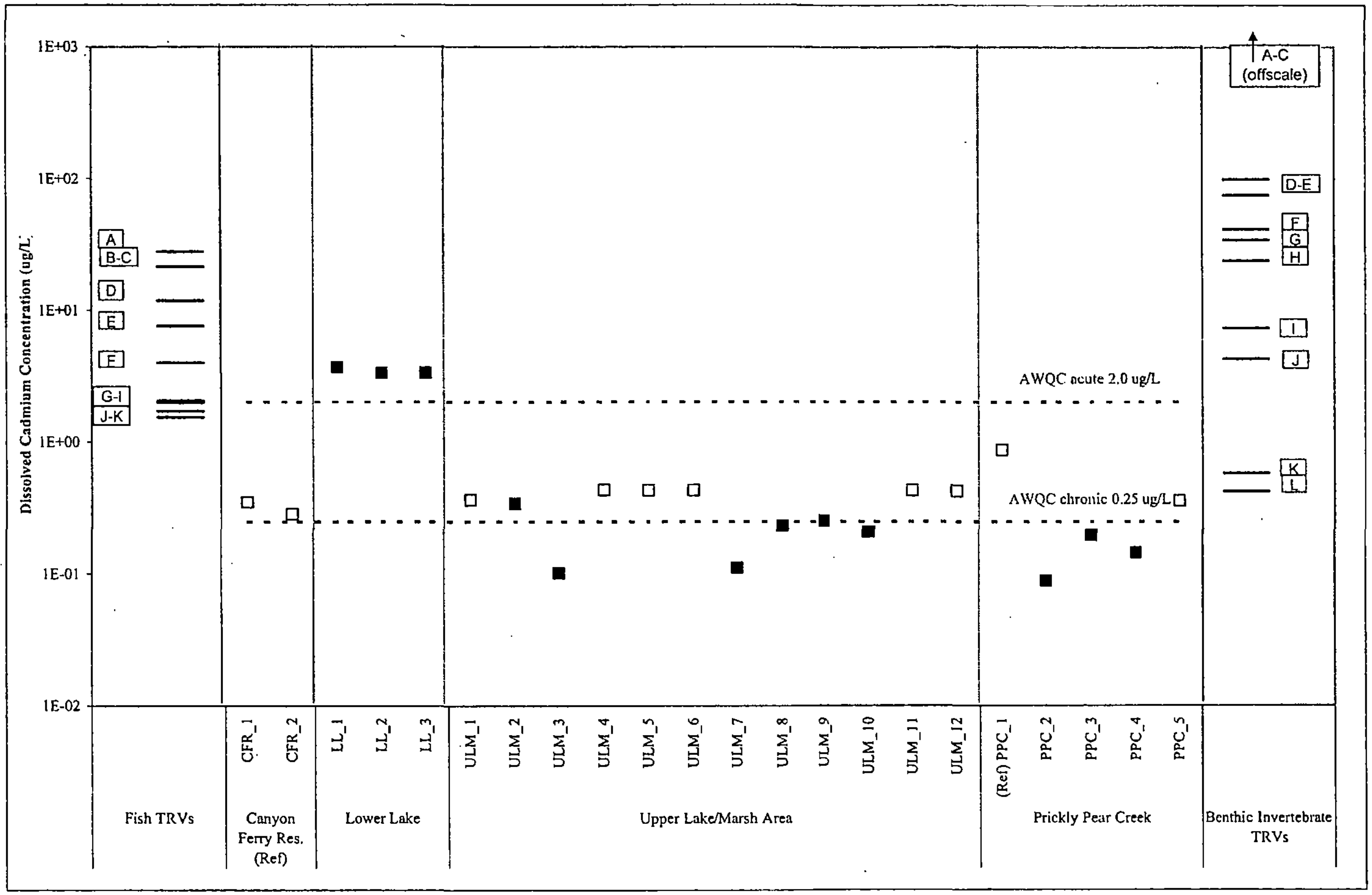
	FISH TRVs (ug/L)	
A	12,900	Bluegill, acute
B	12,850	Rainbow trout (fry), acute
C	10,900	Fathead minnow, acute
D	1,616	Fathead minnow, chronic

Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Note: Detects that visually appear to be lower than non-detects represent results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

	BENTHIC TRVs (ug/L)	
A	12,850	Amphipod (Gammarus sp.), acute
B	12,850	Caddisfly (larvae), acute
C	9,070	Daphnia, acute
D	3,218	Daphnia, chronic
E	1,735	Ceriodaphnia, acute
F	250	Hydra, acute

Figure 5-1b
Comparison of Cadmium Concentrations in Surface Water with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



All measured concentrations and TRVs normalized to a hardness of 100 mg/L.
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Note: Detects that visually appear to be lower than non-detects represent results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

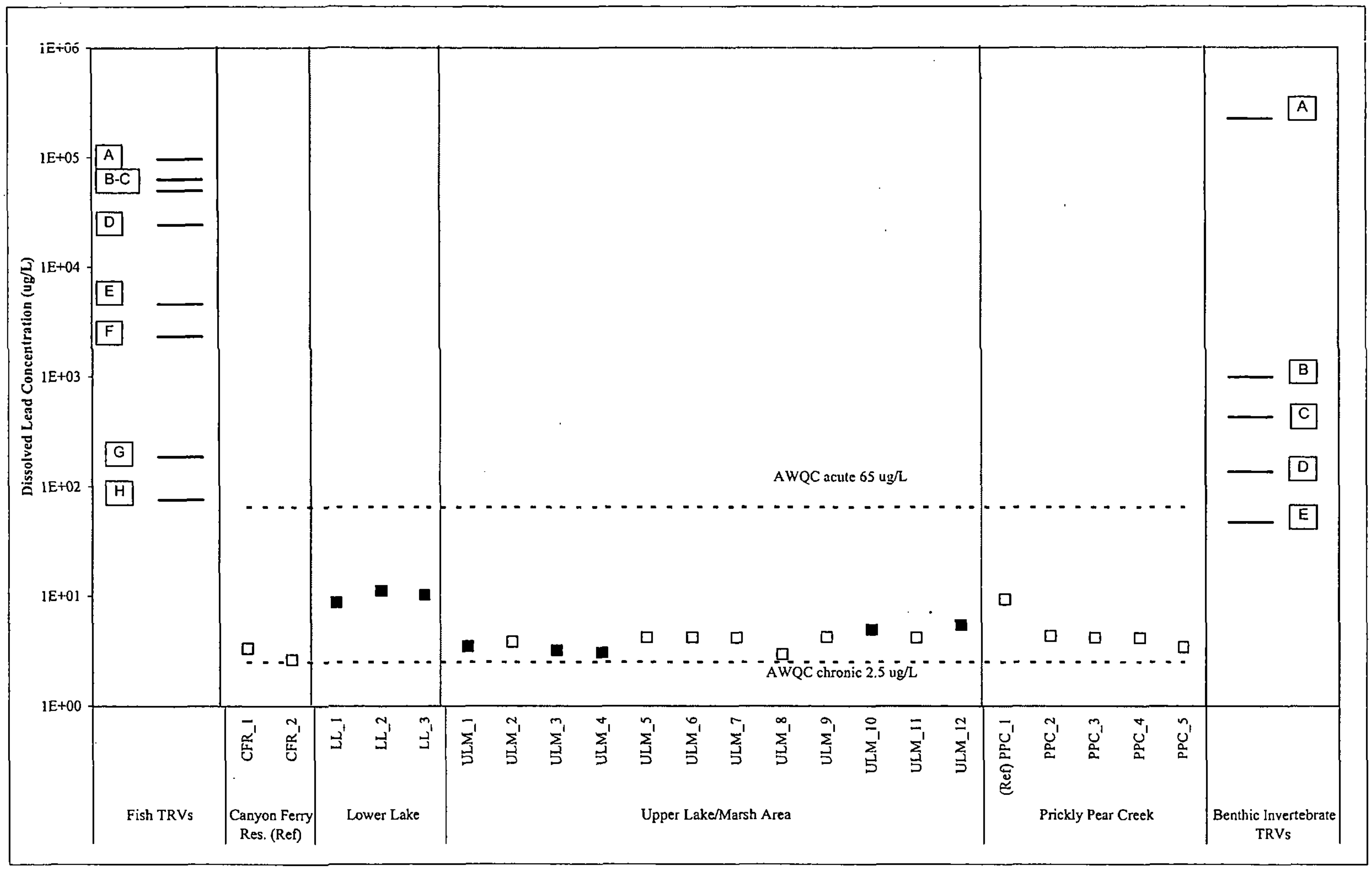
FISH TRVs (ug/L)

A	2995	White sucker, acute
B	27.89	Fathead minnow, acute
C	21.52	Colorado squawfish, acute
D	11.86	White sucker, chronic
E	7.60	Brown trout, chronic
F	4.02	Brook trout, chronic
G	2.05	Bull trout, acute
H	2.01	Rainbow trout, acute
I	1.99	Rainbow trout, chronic
J	1.71	Brook trout, acute
K	1.54	Brown trout, acute

BENTHIC TRVs (ug/L)

A	92,513	Midge, (Chironomus sp.) acute
B	5,891	Tubificid worm, (Rhyacodrilus sp.) a
C	2,175	Mayfly, (Ephemerella sp.) acute
D	99.2	Snail, (Aplexa sp.) acute
E	75.1	Amphipod, (Gammarus sp.) acute
F	41.3	Cladoceran, (Ceriodaphnia sp.) chron
G	34.3	Cladoceran, (Ceriodaphnia sp.) acute
H	23.8	Cladoceran, (Daphnia sp.) acute
I	7.3	Snail, (Aplexa sp.) chronic
J	4.3	Midge, (Chironomus sp.) chronic
K	0.58	Cladoceran, (Daphnia sp.) chronic
L	0.42	Amphipod, (Hyalella sp.) chronic

Figure 5-1c
Comparison of Lead Concentrations in Surface Water with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



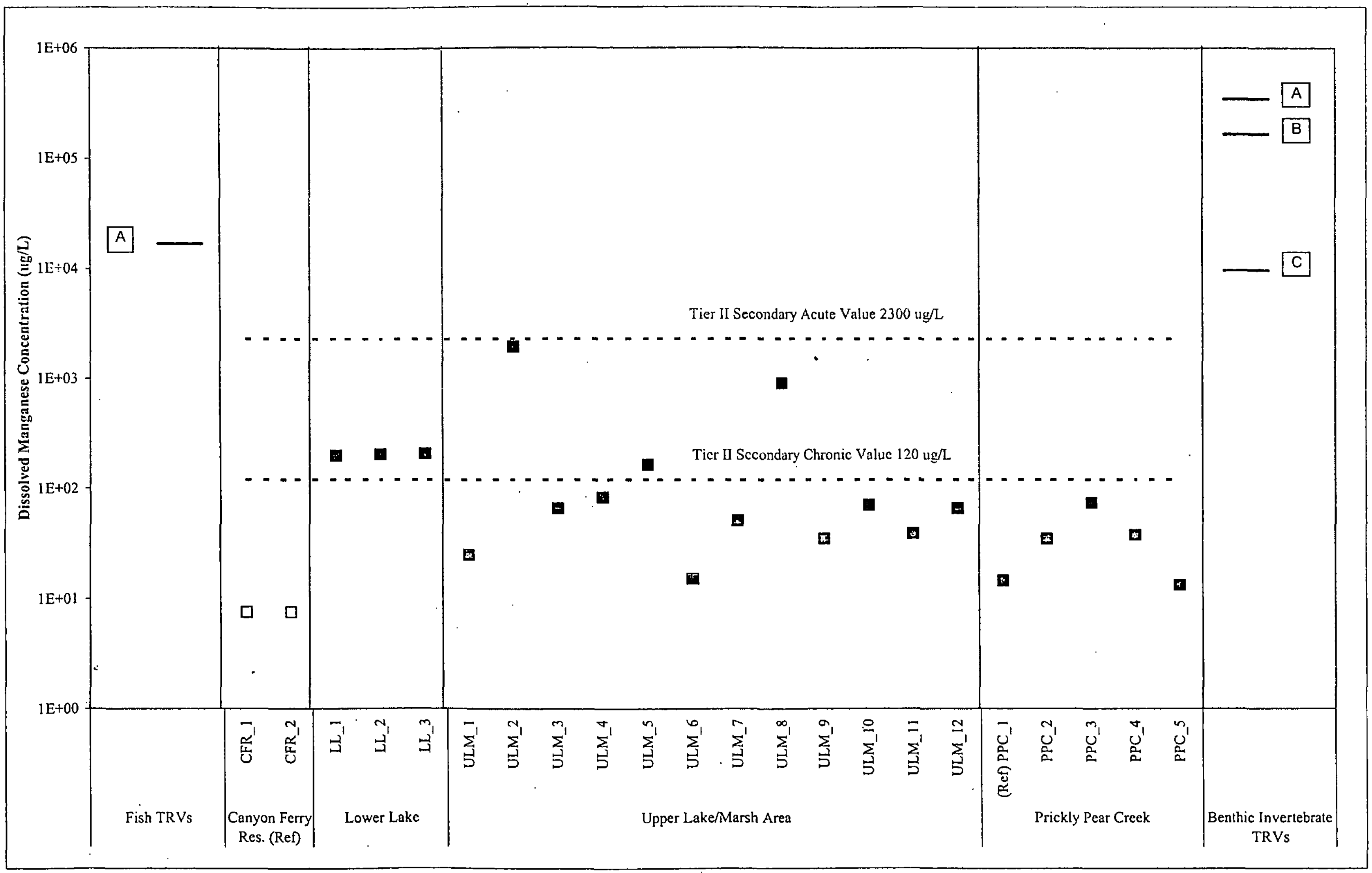
All measured concentrations and TRVs normalized to a hardness of 100 mg/L.
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Note: Detects that visually appear to be lower than non-detects represent results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

	FISH TRVs (ug/L)	
A	96,629	Goldfish, acute
B	63,215	Guppy, acute
C	49,997	Bluegill, acute
D	24,315	Fathead minnow, acute
E	4,607	Brook trout, acute
F	2,340	Rainbow trout, acute
G	187	Brook trout, chronic
H	76	Rainbow trout, chronic

	BENTHIC TRVs (ug/L)	
A	225,469	Midge, (Tanytarsus sp.) acute
B	994	Snail, (Aplexa sp.) acute
C	428	Cladoceran, (Daphnia sp.) acute
D	136	Amphipod, (Gammarus sp.) acute
E	47	Cladoceran, (Daphnia sp.) chronic

Figure 5-1d
Comparison of Manganese Concentrations in Surface Water with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



FISH TRVs (ug/L)		
A	16,800	Fathead minnow, acute

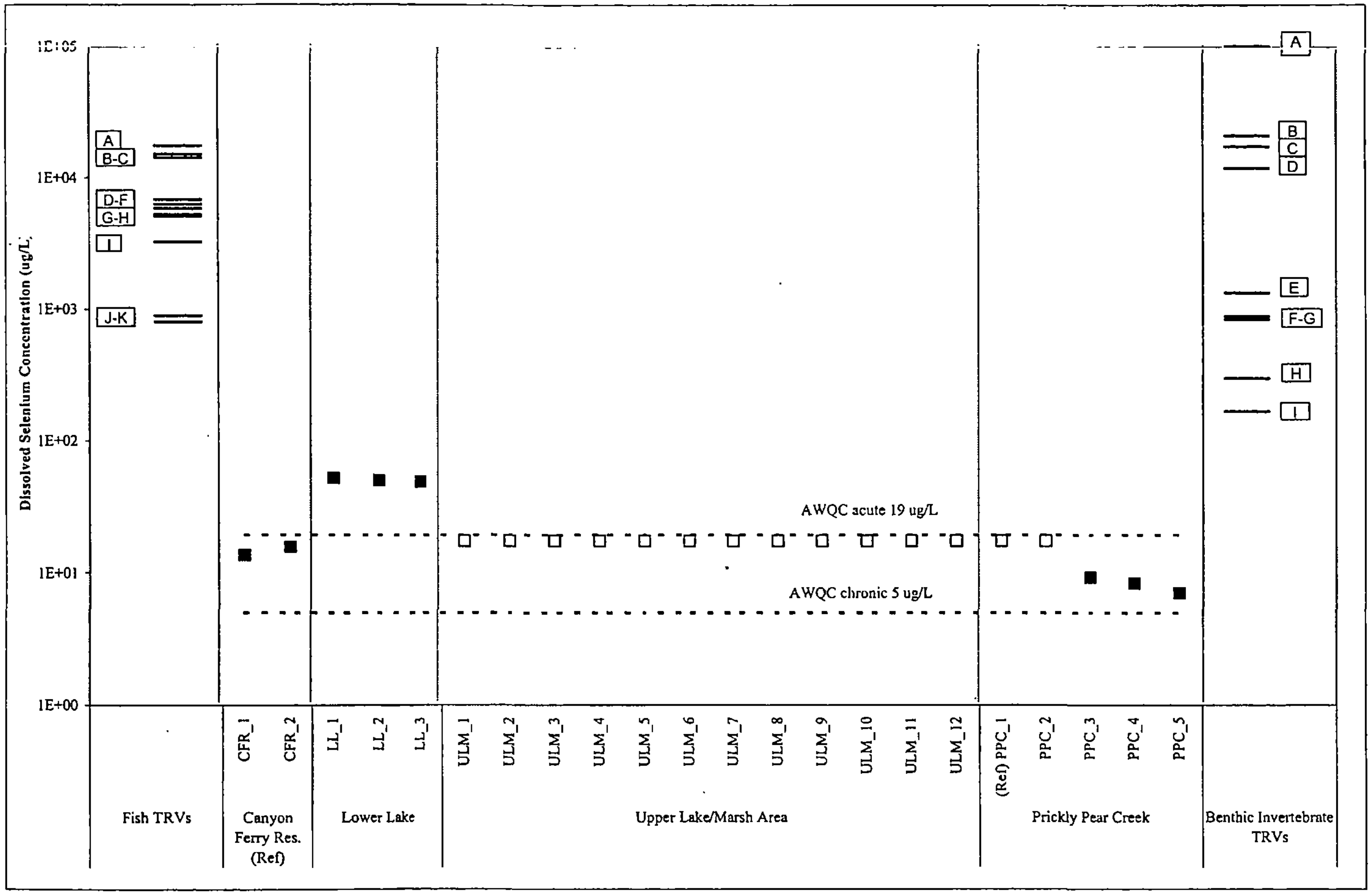
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

BENTHIC TRVs (ug/L)		
A	347000	Amphipod (Crangonyx sp.), acute
B	166500	Isopod (Asellus sp.), acute
C	9675	Daphnia, acute

SW Tox by Species_Mn.xls: Mn Graph
1/25/2005

Figure 5-1e

Comparison of Selenium Concentrations in Surface Water with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



FISH TRVs (ug/L)

A	17,500	Common carp, acute
B	15,088	Wh. Sucker, acute
C	14,250	Bluegill, acute
D	6,800	Channel catfish, acute
E	6,300	Mosquitofish, acute
F	5,850	Yellow perch, acute
G	5,245	Rainbow trout, acute
H	5,100	Brook trout, acute
I	3,250	Flagfish, acute
J	892	Striped bass, acute
K	801	Fathead minnow, acute

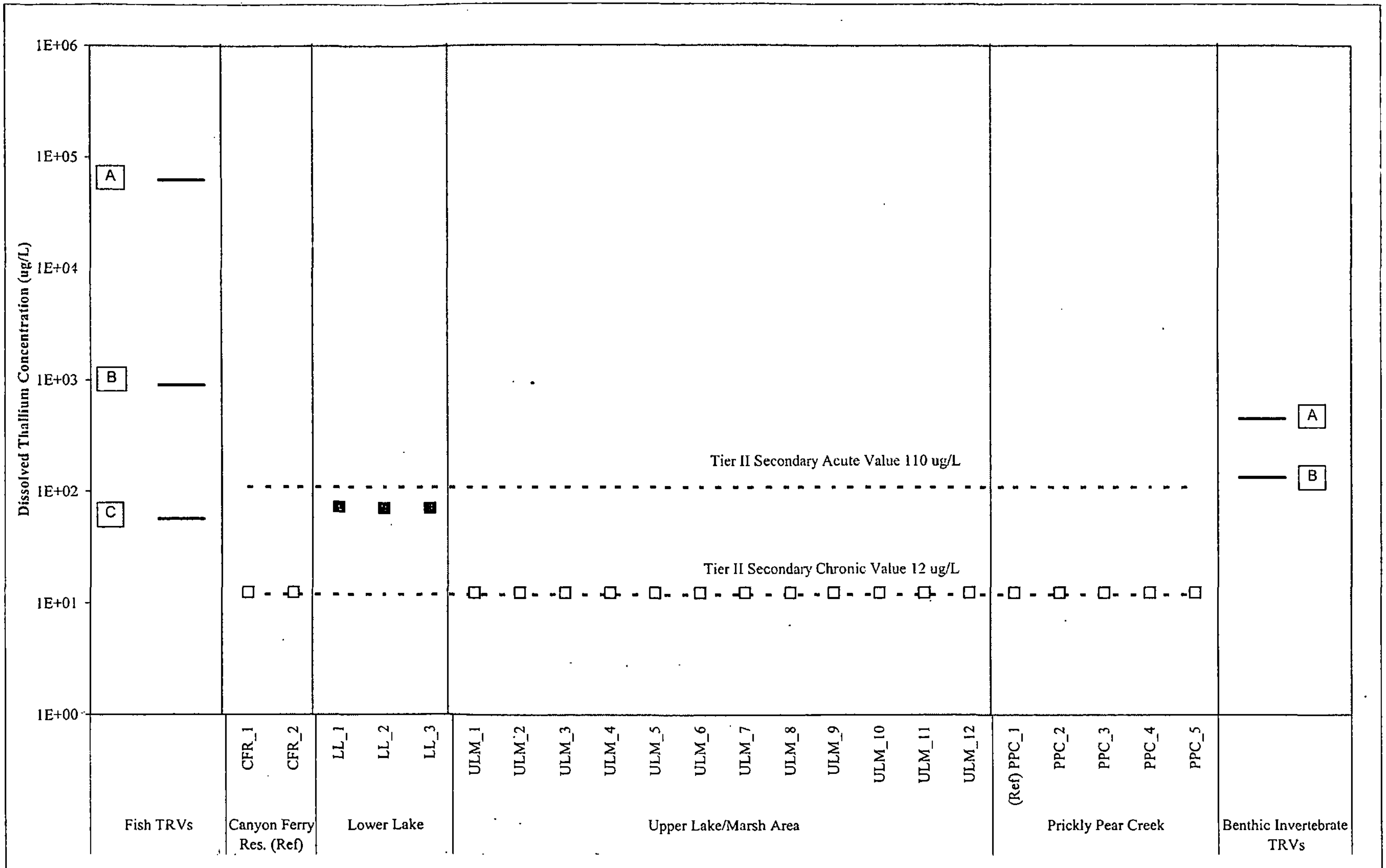
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Note: Detects that visually appear to be lower than non-detects represent results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

BENTHIC TRVs (ug/L)

A	101,500	Leech, acute
B	21,250	Midge, acute
C	17,455	Snail (Aplexa sp.), acute
D	12,050	Snail (Physa sp.), acute
E	1,352	Amphipod (Gammarus sp.), acute
F	898	Daphnia, acute
G	850	Hydra, acute
H	302	Ceriodaphnia, acute
I	170	Amphipod (Hyalella sp.), acute

Figure 5-1f
Comparison of Thallium Concentrations in Surface Water with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



FISH TRVs (ug/L)		
A	62,950	Bluegill, acute
B	898	Fathead minnow, acute
C	57	Fathead minnow, chronic

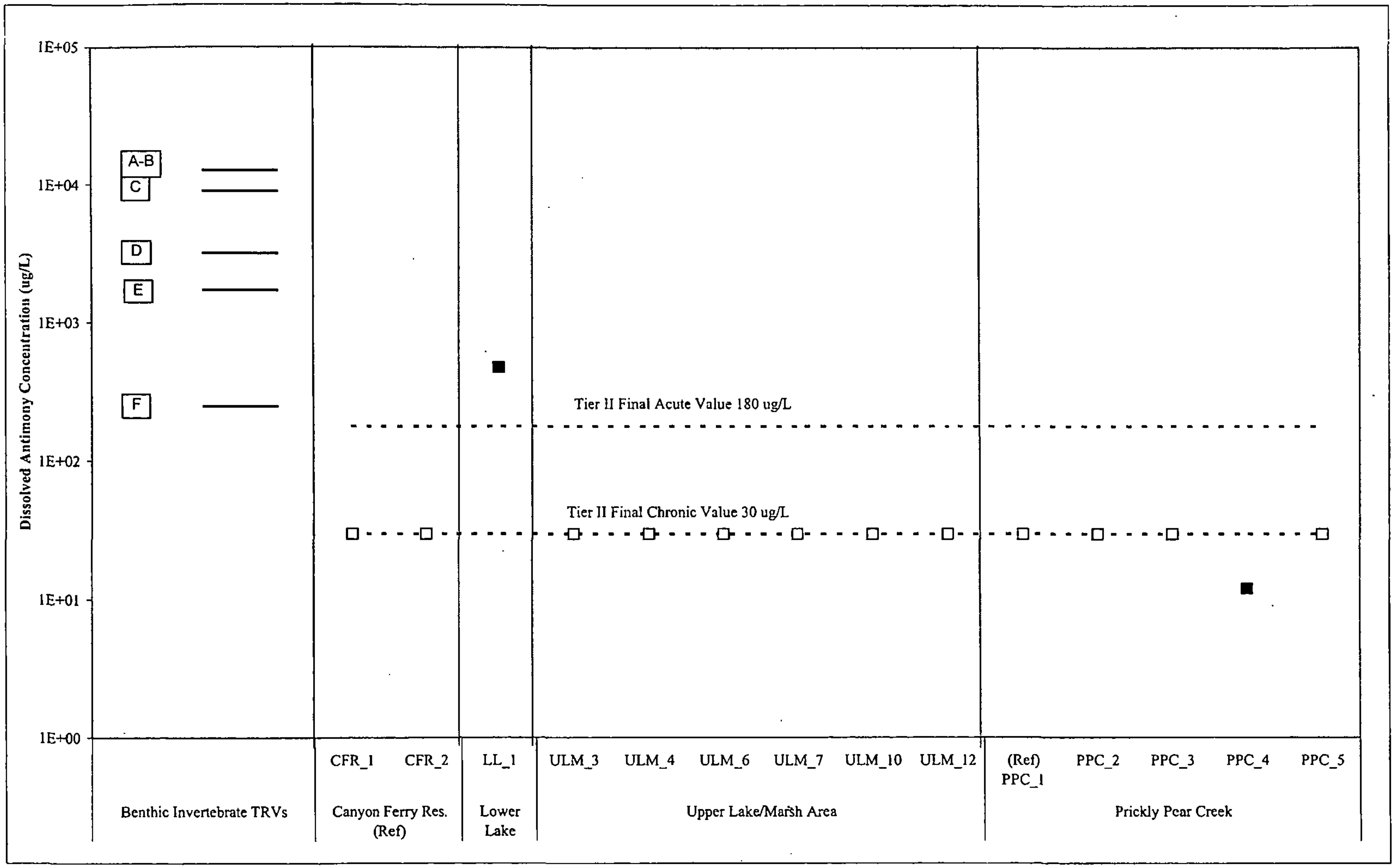
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

BENTHIC TRVs (ug/L)		
A	453	Daphnia, acute
B	135	Daphnia, chronic

SW Tox by Species_Th.xls: Th Graph
1/25/2005

Figure 5-2a

Comparison of Antimony Concentrations in Sediment Porewater with Acute and Chronic Toxicity Values for Benthic Invertebrates



	BENTHIC TRVs (ug/L)	
A	12,850	Amphipod (Gammarus sp.), acute
B	12,850	Caddisfly (larvae), acute
C	9,070	Daphnia, acute
D	3,218	Daphnia, chronic
E	1,735	Ceriodaphnia, acute
F	250	Hydra, acute

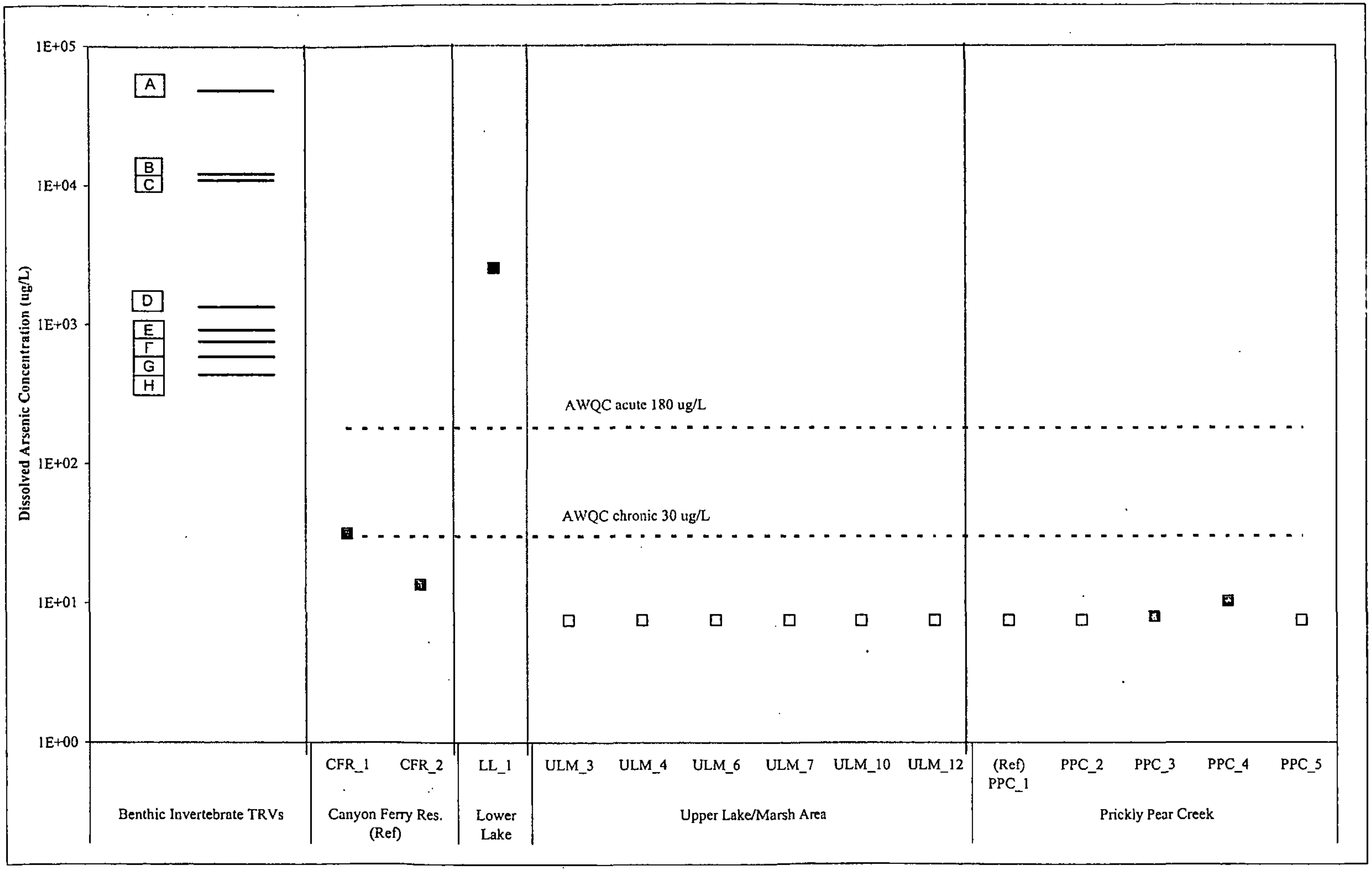
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Note: Detects that visually appear to be lower than non-detects represent results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

PW Tox by Species_Sb.xls: Sb Graph
1/25/2005

Figure 5-2b

Comparison of Arsenic Concentrations in Sediment Porewater with Acute and Chronic Toxicity Values for Benthic Invertebrates

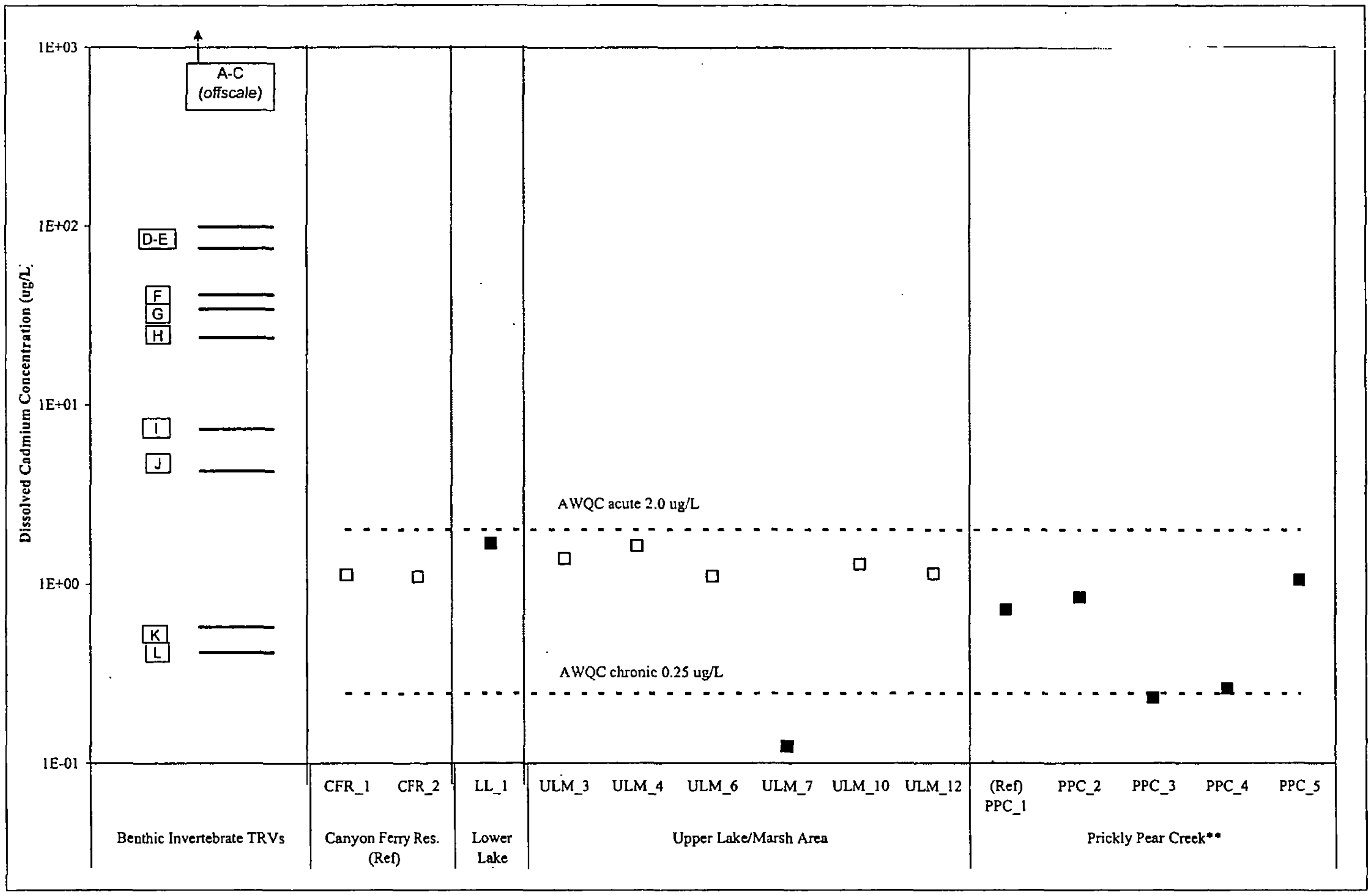


	BENTHIC TRVs (ug/L)	
A	48,500	Midge, acute
B	12,250	Snail (Aplexa sp.), acute
C	11,020	Stonefly, acute
D	1,345	Cladoceran (Daphnia sp.), acute
E	914	Cladoceran (Daphnia sp.), chronic
F	756	Cladoceran (Ceriodaphnia sp.), acute
G	588	Cladoceran (Simocephalus sp.), acute
H	437	Amphipod (Gammarus sp.), acute

Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Figure 5-2c

Comparison of Cadmium Concentrations in Sediment Porewater with Acute and Chronic Toxicity Values for Benthic Invertebrates



BENTHIC TRVs (ug/L)

A	92,513	Midge, (Chironomus sp.) acute
B	5,891	Tubificid worm, (Rhyacodrilus sp.) acute
C	2,175	Mayfly, (Ephemerella sp.) acute
D	99.2	Snail, (Aplexa sp.) acute
E	75.1	Amphipod, (Gammarus sp.) acute
F	41.3	Cladoceran, (Ceriodaphnia sp.) chronic
G	34.3	Cladoceran, (Ceriodaphnia sp.) acute
H	23.8	Cladoceran, (Daphnia sp.) acute
I	7.3	Snail, (Aplexa sp.) chronic
J	4.3	Midge, (Chironomus sp.) chronic
K	0.58	Cladoceran, (Daphnia sp.) chronic
L	0.42	Amphipod, (Hyalella sp.) chronic

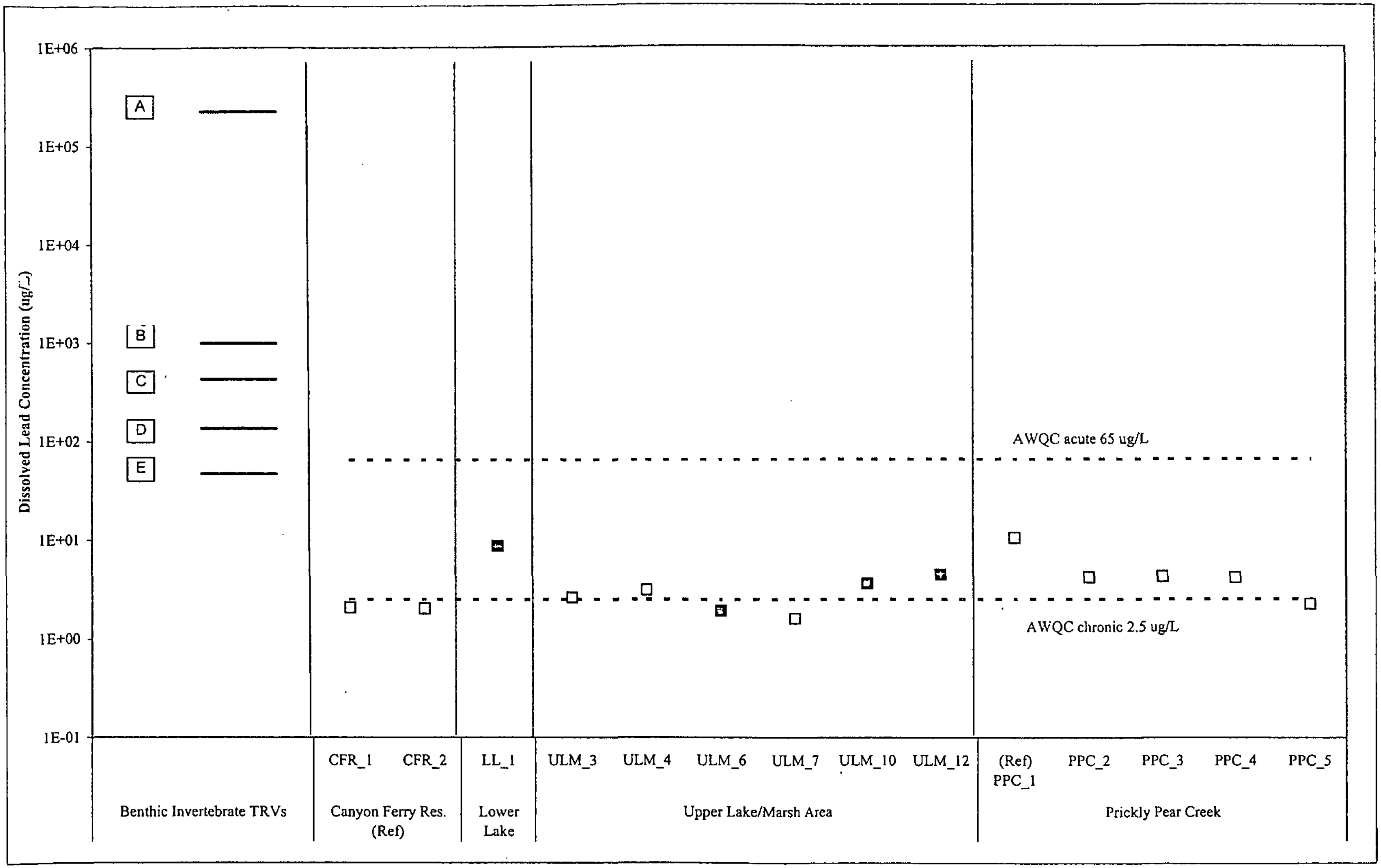
All measured concentrations and TRVs normalized to a hardness of 100 mg/L.
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

** Sufficient volume was available to analyze samples via ICP-AES and MS in order to obtain lower detection limits.

Note: Detects that visually appear to be lower than non-detects represent samples analyzed by MS and/or results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

Figure 5-2d

Comparison of Lead Concentrations in Sediment Porewater with Acute and Chronic Toxicity Values for Benthic Invertebrates



	BENTHIC TRVs (ug/L)	
A	225,469	Midge, (Tanytarsus sp.) acute
B	994	Snail, (Aplexa sp.) acute
C	428	Cladoceran, (Daphnia sp.) acute
D	136	Amphipod, (Gammarus sp.) acute
E	47	Cladoceran, (Daphnia sp.) chronic

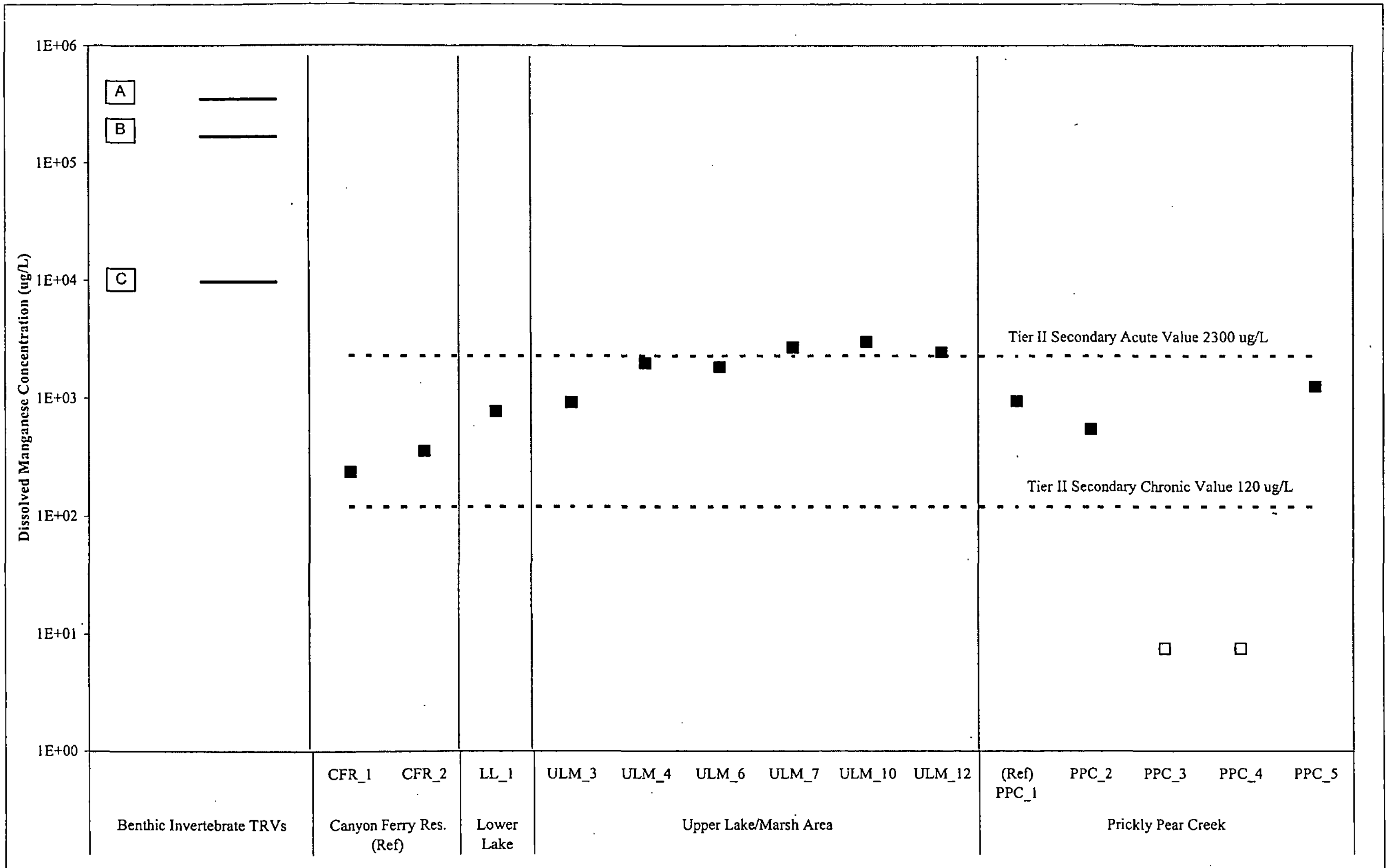
All measured concentrations and TRVs normalized to a hardness of 100 mg/L.
Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Note: Detects that visually appear to be lower than non-detects represent results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

PW Tox by Species_Pb.xls: Pb Graph
1/25/2005

Figure 5-2e

Comparison of Manganese Concentrations in Sediment Porewater with Acute and Chronic Toxicity Values for Benthic Invertebrates



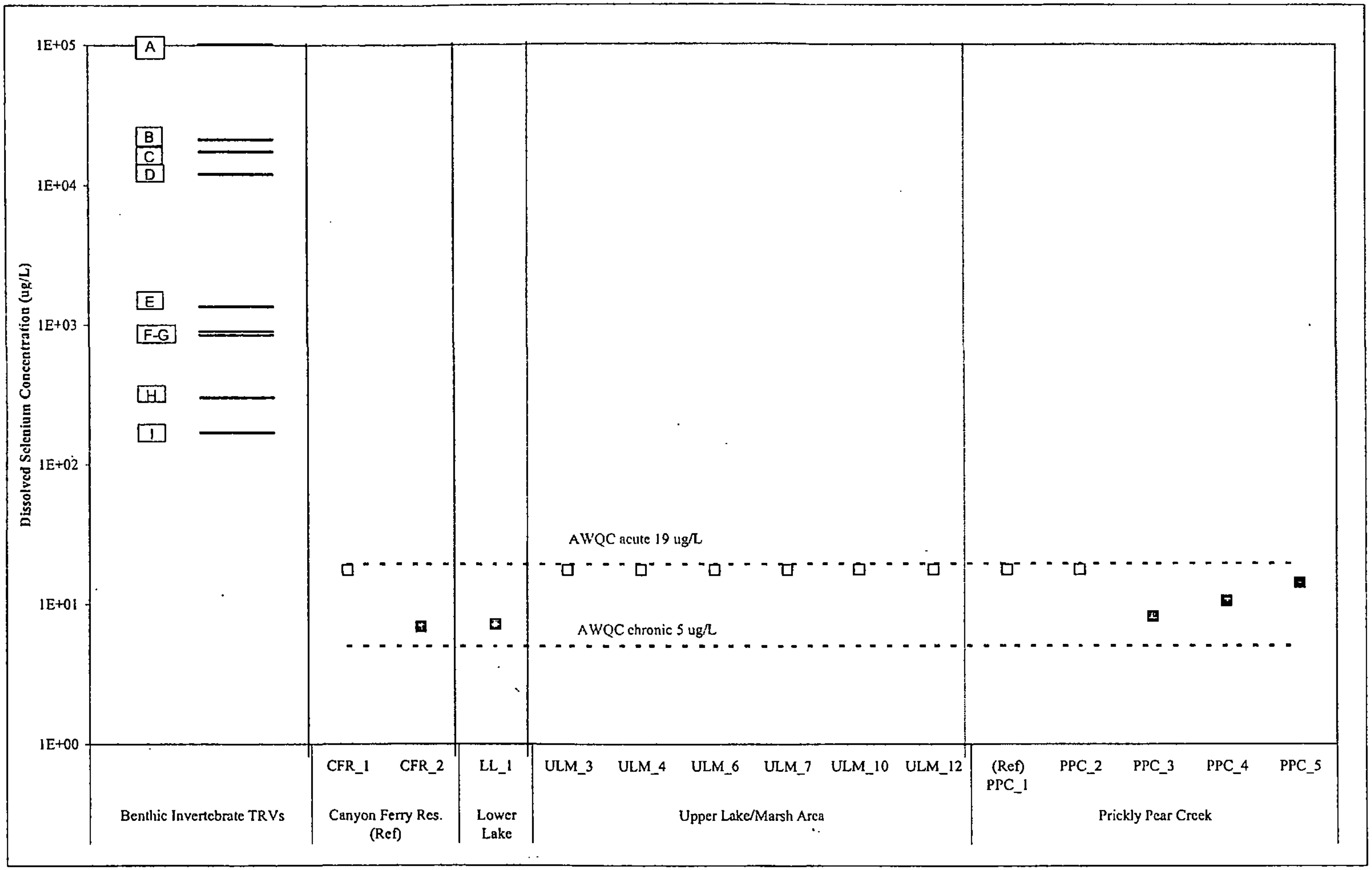
BENTHIC TRVs (ug/L)		
A	347,000	Amphipod (Crangonyx sp.), acute
B	166,500	Isopod (Asellus sp.), acute
C	9,675	Daphnia, acute

Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

PW Tox by Species_Mn.xls: Mn Graph
1/25/2005

Figure 5-2f

Comparison of Selenium Concentrations in Sediment Porewater with Acute and Chronic Toxicity Values for Benthic Invertebrates



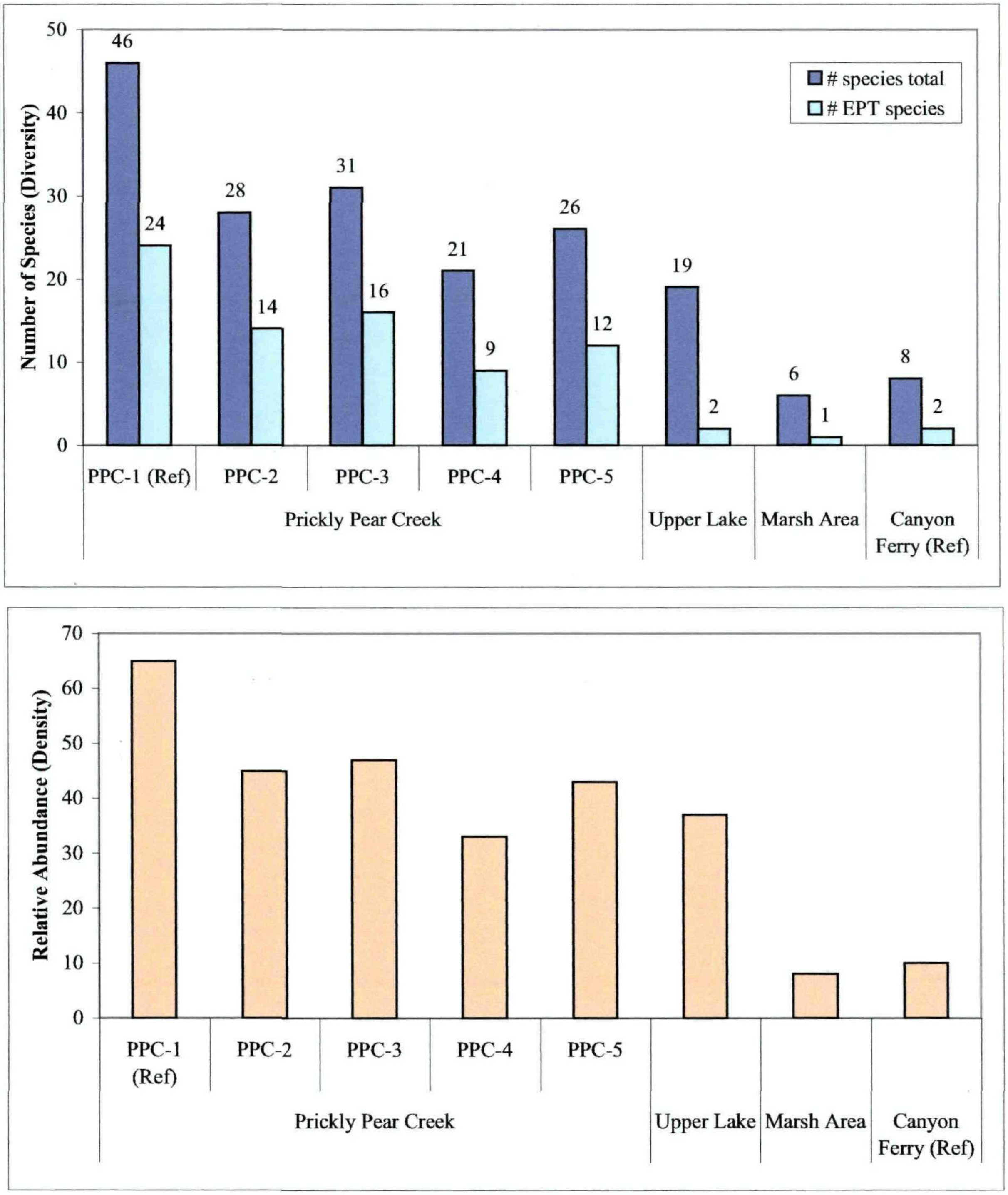
	BENTHIC TRVs (ug/L)	
A	101500	Leech, acute
B	21250	Midge, acute
C	17455	Snail (Aplexa sp.), acute
D	12050	Snail (Physa sp.), acute
E	1352	Amphipod (Gammarus sp.), acute
F	898	Daphnia, acute
G	850	Hydra, acute
H	302	Ceriodaphnia, acute
I	170	Amphipod (Hyalella sp.), acute

Non-detects are displayed as open squares (plotted at 1/2 the detection limit).

Note: Detects that visually appear to be lower than non-detects represent results in which concentrations were J-qualified (estimated). The detection limits (DLs) provided by the analytical laboratory were the contract-required DLs (CRDL) and not the method DL (MDL).

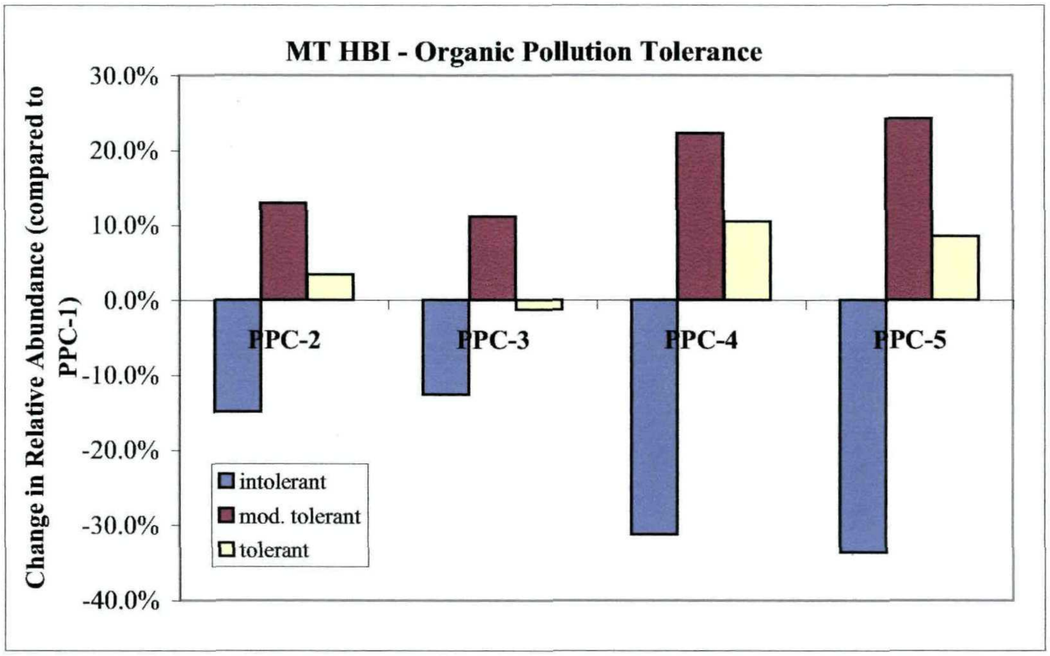
PW Tox by Species_Se.xls: Se Graph
1/25/2005

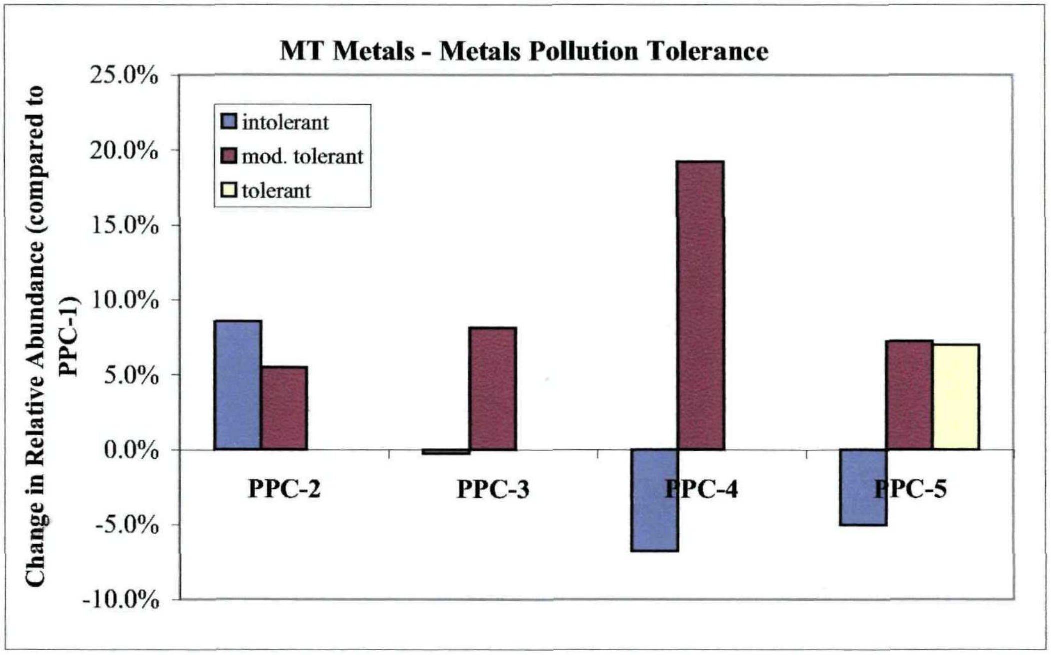
Figure 5-3
Benthic Invertebrate Community Metrics



Note: Due to low water levels at the time of sampling, the Canyon Ferry Reservoir sample was determined to be an unsuitable reference for the Upper Lake and marsh area samples.

Figure 5-4
Comparison of Site Benthic Invertebrate Relative Abundance to Reference (PPC-1) based on Tolerance Ranking





Change in Relative Abundance (RA) for Species 'x' = [Site RAx / SUM(Site RAi)] - [Ref RAx / SUM(Ref RAi)]
Change in RA across all species = SUM(Change in RAi) within each tolerance ranking

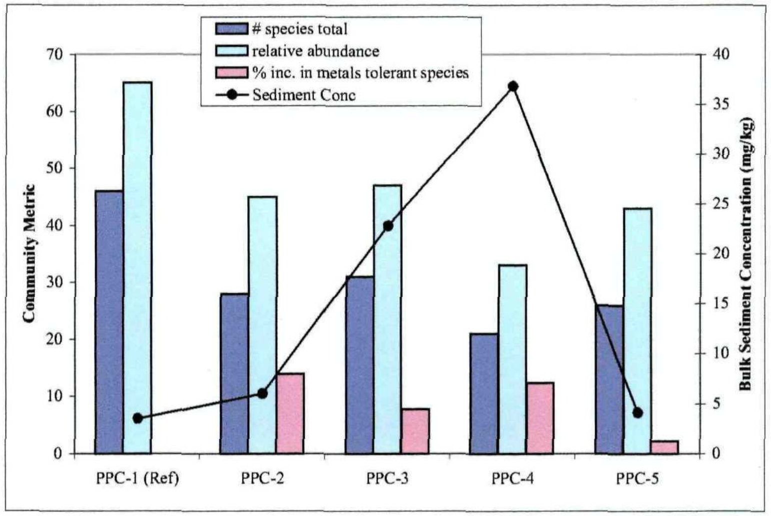
Tolerance Rankings:
intolerant = 0 to 3
moderately tolerant = 4 to 6
tolerant = 7 to 10

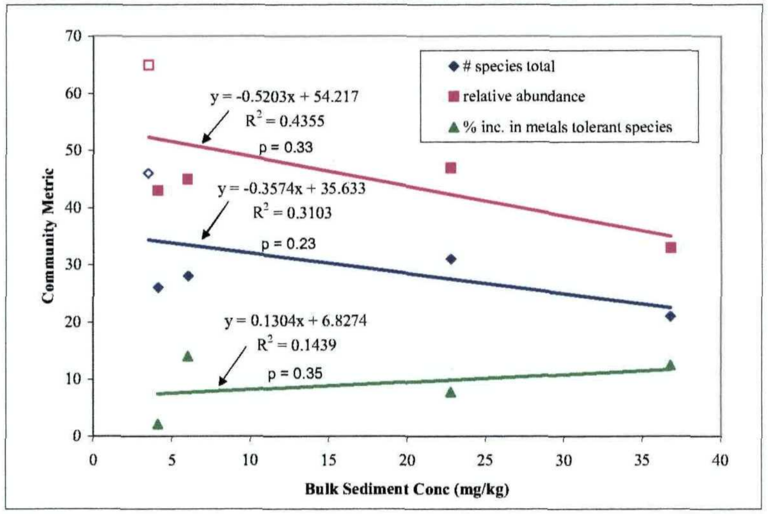
Figure 5-5

Comparison of Community Metrics to Measured Concentrations in Bulk Sediment and Sediment Porewater

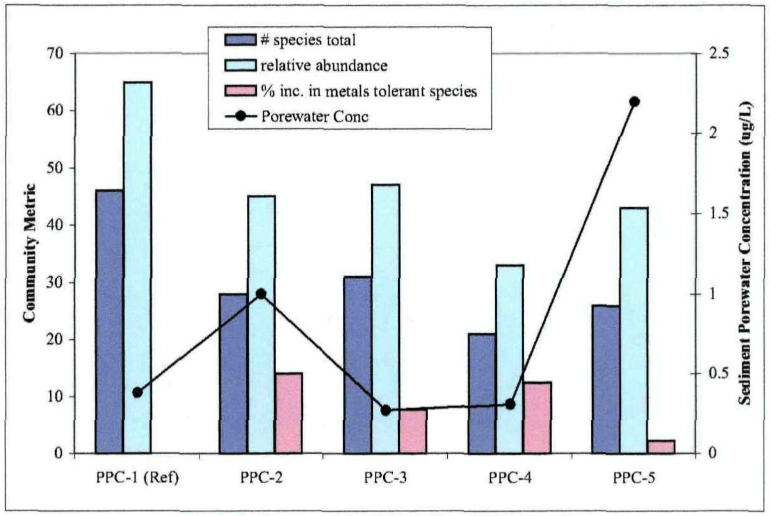
CADMIUM

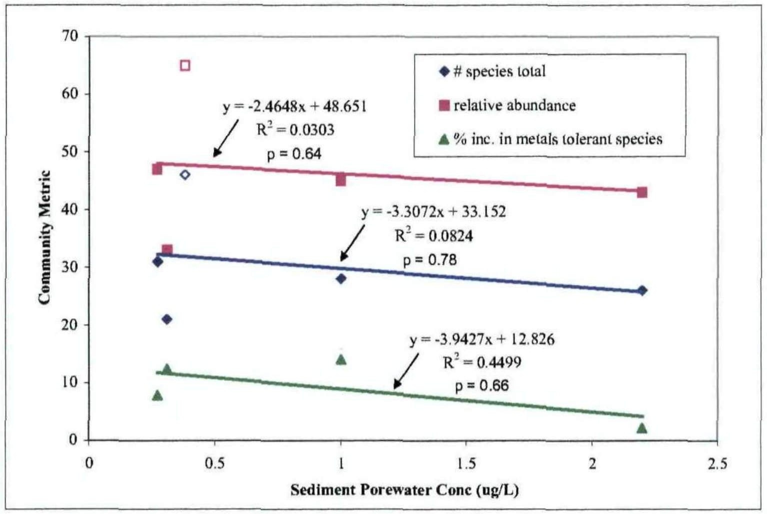
Comparison with Bulk Sediment





Comparison with Sediment Porewater





Open symbols designate the reference location (PPC-1).

Community Results.xls, PPC Exp vs Resp
1/25/2005

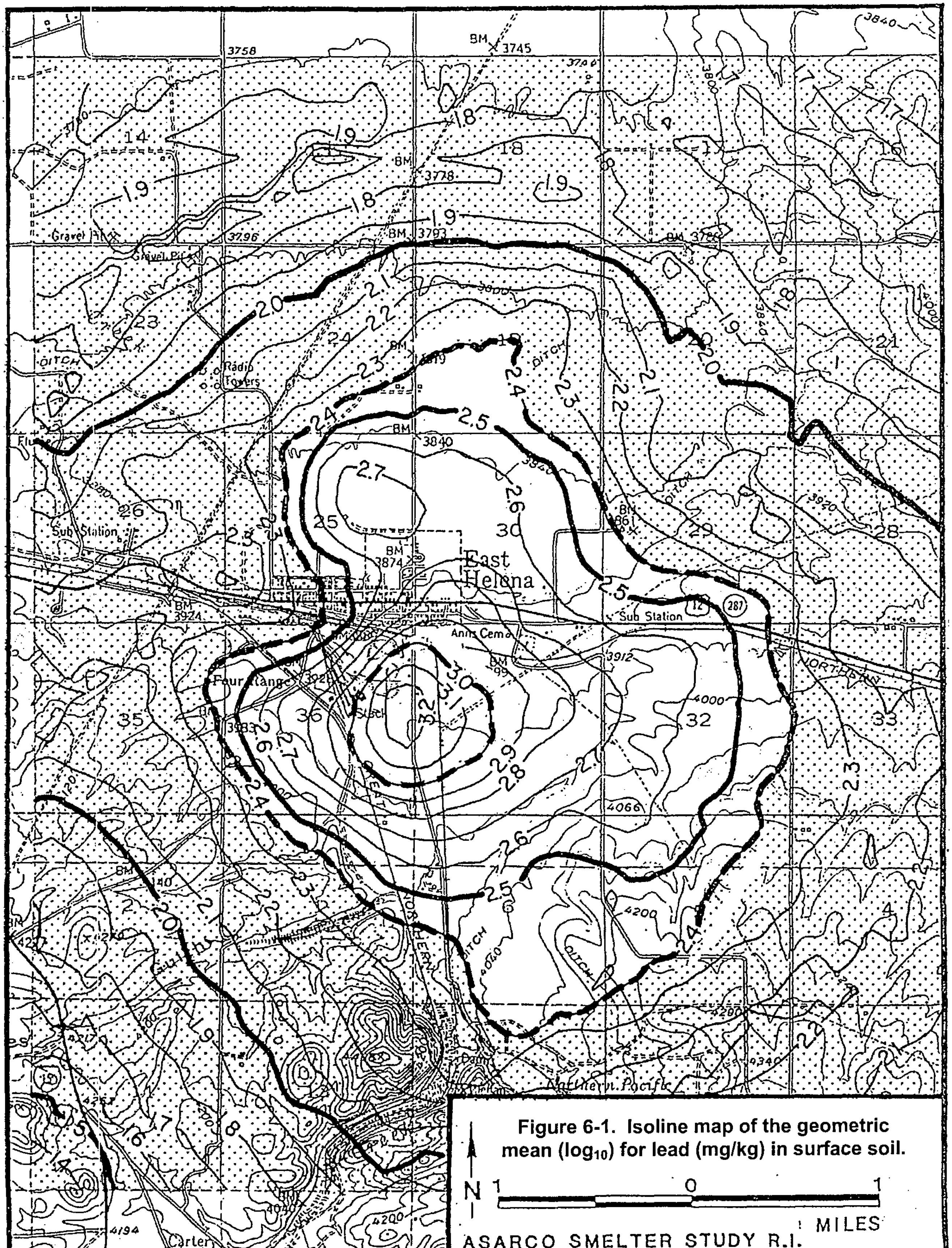


Figure 6-1. Isoline map of the geometric mean ($\log_{10}$) for lead (mg/kg) in surface soil.

Source: Remedial Investigation (CH2MHill, 1987)

TABLES

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Table 3-1
Summary of Data Collected in Previous Investigations of the East Helena Site and Helena Valley

Investigation - ***Collection Date***	**Media Collected**	**Locations Evaluated**	**Analyses Performed**
CH2MHill (1987), Remedial Investigation *- 1983*	Soil (4 depth strata: 0-4", 4-8", 8-15", 15-30")	Soils: 157 sampling stations on-site & in the Helena Valley (including 3 reference stations)	Bulk Metals: Al, Sb, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Tl, Sn, V, Zn (metals analyzed for extractable are underlined above)
	Plant tissue (forage/grass, barley/wheat, grain)	Plants: 58 sampling stations on-site & in the Helena Valley (including 3 reference stations)	Metals: As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Ag, V, Zn
	Cattle blood (whole, serum) & hair	Livestock: 8 site herds, 1 reference herd (N=178 animals)	Metals: As, Cd, Pb, Zn
Hunter/ESE (1989), Endangerment Assessment *- 1989*	Surface water	Lower Lake: 1 station Prickly Pear Creek (downstream): 13 stations Wilson Ditch: 4 stations	N/A, only summary statistics for As, Cd, Cu, Fe, Pb, Mn, Zn are provided
	Sediment	Prickly Pear Creek (downstream): 6 stations Wilson Ditch: 3 stations	N/A, only summary statistics for As, Cd, Cu, Fe, Pb, Mn, Zn are provided
USFWS (1997) - *1987, 1991, 1992*	Abiotic: sediment Biotic: benthic invertebrate tissue[1], fish tissue & blood[1] (rainbow & brook trout, sucker), mallard blood[2]	Prickly Pear Creek (upstream): 3 abiotic stations, 1 biotic station Prickly Pear Creek (downstream): 5 abiotic stations, 1 biotic station Lake Helena: 2 abiotic stations, 1 biotic station Canyon Ferry Reservoir (reference location): 1 abiotic & biotic station	Metals: As, Cd, Cu, Pb, Zn Blood (fish & mallard): δ-amino levulinic acid dehydratase (ALAD), lead, hemoglobin (HB), free erythrocyte protoporphyrin (ZPP)

Table 3-1 (continued)
Summary of Data Collected in Previous Investigations of the East Helena Site and Helena Valley

Investigation - ***Collection Date***	**Media Collected**	**Locations Evaluated**	**Analyses Performed**
USFWS (1997) Addendum - *March 1993*	Abiotic: sediment Biotic: fish tissue (rainbow & brown trout, sucker)	Prickly Pear Creek (upstream): 1 abiotic & biotic station Prickly Pear Creek (downstream): 1 abiotic & biotic station Lake Helena: 2 abiotic stations Canyon Ferry Reservoir (reference location): 1 abiotic & biotic station	Mercury
USGS (1998) - *March & July 1995*	Abiotic: surface water, sediment[1] Biotic: benthic invertebrates tissue[1], fish tissue (sucker, carp)	Prickly Pear Creek (downstream): 3 abiotic stations, 1 biotic station Lake Helena: 4 abiotic stations, 2 biotic stations	Metals: Al, As, Ba, Bc, Bo, Cd, Cr, Cu, Pb, Mg, Mn, Hg, Mo, Ni, Se, St, V, Zn

[1] Data available for Prickly Pear Creek only
[2] Data available for Lake Helena only

Table 3-2
Samples Collected During the 2003 Ecological Field Investigation

<table>
<tr><th>Location</th><th>Station ID</th><th>Surface Water</th><th>Bulk Sediment</th><th>Sediment Porewater</th><th>Benthic Invertebrates</th><th>Aquatic Plants/Algae</th><th>Fish</th><th>Sediment Toxicity Test</th><th>Benthic Invertebrate Community</th></tr>
<tr><td rowspan="3">Lower Lake</td><td>LL_1</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>LL_2</td><td>x</td><td>x</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>LL_3</td><td>x</td><td>x</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="12">Upper Lake/Marsh Area</td><td>ULM_1</td><td>x</td><td>x</td><td></td><td>x</td><td>x</td><td rowspan="12">x (a)</td><td></td><td rowspan="12">x (c)</td></tr>
<tr><td>ULM_2</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>ULM_3</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td>ULM_4</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td>ULM_5</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>ULM_6</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td>ULM_7</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td>ULM_8</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>ULM_9</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>ULM_10</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td>x</td></tr>
<tr><td>ULM_11</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>ULM_12</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td></tr>
<tr><td rowspan="2">Canyon Ferry Reservoir (Ref)</td><td>CFR_1</td><td>x</td><td>x</td><td>x</td><td></td><td>x</td><td rowspan="2">x (b)</td><td>x</td><td rowspan="2">x (d)</td></tr>
<tr><td>CFR_2</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td>x</td></tr>
<tr><td rowspan="5">Prickly Pear Creek</td><td>PPC_1 (Ref)</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>PPC_2</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>PPC_3</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>PPC_4</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>PPC_5</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td></td><td>x</td></tr>
</table>

(a) 1 forage fish composite sample, several rainbow trout samples (1 whole body, 2 fillet, 1 liver, 1 kidney, 2 stomach contents)
(b) 1 forage composite sample
(c) 1 composite sample for Upper Lake, 1 composite sample for Marsh Area
(d) 1 composite sample

Table 4-1
Comparison of Terrestrial Plant and Invertebrate Toxicity Benchmarks for Soil

Analytes	Eco-SSL Benchmarks (mg/kg)		ORNL Benchmarks (mg/kg)		
	Terrestrial Plants	Terrestrial Invertebrates	Terrestrial Plants	Terrestrial Invertebrates	Microbes
Aluminum	(a)	(a)	50	--	600
Antimony	--	78	5.0	--	--
Arsenic	P	P	10	60	100
Barium	--	330	500	--	3000
Beryllium	--	40	10	--	--
Cadmium	32	140	4.0	20	20
Chromium	P	P	1.0	0.4	10
Cobalt	13	--	20	--	1000
Copper	P	P	100	50	100
Iron	(b)	--	--	--	200
Lead	110	1700	50	500	900
Manganese	P	P	500	--	100
Mercury	--	--	0.3	0.1	30
Nickel	P	P	30	200	90
Selenium	P	P	1.0	70	100
Silver	P	P	2.0	--	50
Thallium	--	--	1.0	--	--
Vanadium	--	--	2.0	--	20
Zinc	P	P	50	100	100

P = Pending
(a) Aluminum is expected to be a contaminant of potential concern only when soil pH is below 5.5.
(b) Iron is an essential micronutrient for plants, and is not expected to be a primary contaminant of concern at most sites.

Benchmark Sources:
Eco-SSL - USEPA (2003c)
ORNL - Efroymson (1997a,b)

Table 5-1
Surface Water Toxicity Benchmarks for Aquatic Receptors

Analyte	ACUTE				CHRONIC				
	NAWQC - Acute (ug/L) [1]	GLWQI Tier II SAV (ug/L) [2]	USEPA R4 Acute (ug/L) [2]	**Surface Water Acute Benchmark (ug/L)**	NAWQC - Chronic (ug/L) [1]	GLWQI Tier II SCV (ug/L) [2]	USEPA R4 - Chronic (ug/L) [2]	Other (ug/L) [2]	**Surface Water Chronic Benchmark (ug/L)**
Aluminum	750 [6]	--	750	750	87	--	87	--	87
Antimony	--	180	1300	180	--	30	160	--	30
Arsenic	340 [9, 10]	--	360	340	150 [9, 10]	--	190	--	150
Barium	50,000 [8]	110	--	50,000	5,000 [3]	--	--	--	5,000
Beryllium	--	35	16	35	--	0.66	0.53	--	0.66
Boron	--	30	--	30	--	1.6	--[13]	8,830 LCV Daphnids	1.60
Cadmium	2.0 [4, 10]	--	3.92	2.01	0.25 [4, 10]	--	1.1	--	0.25
Calcium	--	--	--	no benchmark	--	--	--	116,000 LCV Daphnids	116000
Chromium III	570 [4, 10]	--	1,740	570	74 [4, 10]	--	207	--	74
Chromium VI	16 [10]	--	16	16	10.6 [10]	--	11	--	11
Cobalt	--	1,500	--	1,500	--	23	--	--	23
Copper	13 [4, 10]	--	17.7	13	8.96 [4, 10]	--	11.8	--	9
Cyanide	22 [12]	--	22	22	5.2 [12]	--	5.2	5.0	5.2
Iron	--	--	--	no benchmark	1,000	--	1,000	300 CCME WQG	1,000
Lead	65 [4, 10]	--	81.6	65	2.52 [4, 10]	--	3.18	--	2.5
Magnesium	--	--	--	no benchmark	--	--	--	82,000 LCV Daphnids	82,000
Manganese	--	2,300	--	2,300	--	120	--	--	120
Mercury	1.2	--	2.4	1.2	0.65	1.3	0.012	--	0.65
Molybdenum	--	16,000	--	16,000	--	370	--	--	370
Nickel	468 [4, 10]	--	1420	468	52.0 [4, 10]	--	158	--	52
Potassium	--	--	--	no benchmark	--	--	--	53,000 LCV Daphnids	53,000
Selenium	19 [11]	--	20	19	5.0 [11]	--	5.0	--	5.0
Silver	3.4 [4, 10]	--	4.1	3.4	0.3 [3]	0.36	0.012	--	0.3
Sodium	--	--	--	no benchmark	--	--	--	680,000 LCV Daphnids	680,000
Thallium	--	110	140	110	--	12	4	--	12
Vanadium	--	280	--	280	--	20	--	--	20
Zinc	117 [4, 10]	--	117	117	118 [4, 10]	--	106	--	118

1 USEPA, 2002. National Recommended Water Quality Criteria: 2002. November 2002. EPA 822-R-02-047.
2 Suter & Tsao, 1996.
3 Only acute NAWQC available; chronic NAWQC is equal to acute / 10.
4 Metal toxicity is hardness-dependent; values shown are calculated based on a hardness of 100 mg/L.
5 National Irrigation Water Quality Program (1998)
6 Aluminum NAWQC apply to waters with pH of 6.5 - 9.0.
7 Alkalinity NAWQC is the minimum required value.
8 Based on USEPA Gold Book value.
9 NAWQC derived from data for As 3+, but is applied here to total arsenic.
10 NAWQC expressed in terms of the dissolved fraction.
11 NAWQC expressed in terms of the total recoverable fraction.
12 NAWQC expressed in terms of free cyanide.
13 Region 4 value based on minimum standard for long-term irrigation of sensitive crops.

NAWQC = National Ambient Water Quality Criteria
GLQWI = Great Lakes Water Quality Initiative
SAV/SCV = Secondary Acute/Chronic Value
CCME = Canadian Council of Ministers of the Environment
WQG = Water Quality Guidelines
LCV = Lowest Chronic Value

SW Aquatic Benchmarks.xls: SW Bnchmrks
1/25/2005

Table 5-2

Range of Hazard Quotients (Acute - Chronic) for Aquatic Receptors from Direct Contact with Surface Water

	Canyon Ferry Reservoir (Ref)		Lower Lake			Prickly Pear Creek				
						(Ref)	(upstream >>> downstream)			
Station ID	CFR 1	CFR 2	LL 1	LL 2	LL 3	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
ALUMINUM	ND	<1 - <1	ND	ND	ND	ND	ND	ND	ND	ND
ANTIMONY	ND	<1 - <1	**2 - 10**	**2 - 10**	**2 - 10**	ND	ND	ND	ND	ND
ARSENIC	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND	ND	<1 - <1	<1 - <1	ND
BARIUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1
BERYLLIUM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHROMIUM	<1 - <1	<1 - <1	<1 - <1	ND	ND	ND	ND	<1 - <1	ND	ND
COBALT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
IRON	NC - <1	ND	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
MANGANESE	ND	ND	**<1 - 2**	**<1 - 2**	**<1 - 2**	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
MERCURY	ND	ND	<1 - <1	<1 - <1	<1 - <1	ND	ND	ND	ND	ND
POTASSIUM	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
SELENIUM	**<1 - 3**	**<1 - 3**	**3 - 10**	**3 - 10**	**3 - 10**	ND	ND	**<1 - 2**	**<1 - 2**	<1 - <1
SODIUM	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
THALLIUM	ND	ND	**<1 - 6**	**<1 - 6**	**<1 - 6**	ND	ND	ND	ND	ND
VANADIUM	<1 - <1	<1 - <1	ND	ND	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
CADMIUM*	ND	ND	**2 - 20**	**2 - 20**	**2 - 20**	ND	<1 - <1	<1 - <1	<1 - <1	ND
COPPER*	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND	ND	<1 - <1	ND	ND
LEAD*	ND	ND	**<1 - 3**	**<1 - 4**	**<1 - 4**	ND	ND	ND	ND	ND
NICKEL*	ND	ND	<1 - <1	<1 - <1	<1 - <1	ND	ND	ND	ND	ND
SILVER*	<1 - NC	R	<1 - NC	ND	<1 - NC	R	R	<1 - NC	<1 - NC	<1 - NC
ZINC*	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	**2 - 2**	<1 - <1	<1 - <1	<1 - <1	<1 - <1
Hardness (mg/L)	*144*	*180*	*190*	*200*	*207*	*57*	*114*	*118*	*118*	*141*

	Upper Lake/Marsh Area											
Station ID	ULM 1	ULM 2	ULM 3	ULM 4	ULM 5	ULM 6	ULM 7	ULM 8	ULM 9	ULM 10	ULM 11	ULM 12
ALUMINUM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ANTIMONY	ND	<1 - <1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ARSENIC	<1 - <1	ND	ND	ND	<1 - <1	<1 - <1	ND	ND	ND	ND	ND	ND
BARIUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
BERYLLIUM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHROMIUM	<1 - <1	<1 - <1	ND	ND	ND	ND	ND	<1 - <1	ND	ND	ND	ND
COBALT	ND	<1 - <1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
IRON	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
MANGANESE	<1 - <1	**<1 - 20**	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	**<1 - 7**	<1 - <1	<1 - <1	<1 - <1	<1 - <1
MERCURY	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
POTASSIUM	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
SELENIUM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SODIUM	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
THALLIUM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
VANADIUM	<1 - <1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CADMIUM*	ND	<1 - <1	<1 - <1	ND	ND	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND	ND
COPPER*	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
LEAD*	ND	ND	<1 - <1	<1 - <1	ND	ND	ND	ND	ND	**<1 - 2**	ND	**<1 - 2**
NICKEL*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SILVER*	<1 - NC	ND	<1 - NC	ND	ND	ND	ND	ND	ND	ND	ND	ND
ZINC*	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND
Hardness (mg/L)	*139*	*127*	*119*	*116*	*117*	*117*	*118*	*163*	*116*	*121*	*117*	*119*

bold Detected, estimated HQ above a level of concern

ND = Not Detected

NC = Not Calculated, no benchmark available

R = Analytical result rejected by validator

* Acute and chronic benchmarks for these metals are hardness-dependant, and were calculated based on the sample-specific hardness.

Table 5-3
Bulk Sediment Toxicity Benchmarks for Benthic Macroinvertebrates

Analyte	Threshold Effect Concentrations (TEC)[1]					Probable Effect Concentrations (PEC)[2]				
	Consensus-Based TEC (mg/kg) [a]	ARCS TEL (mg/kg) [b]	Other (mg/kg)		Sediment Screening Benchmark (mg/kg)	Consensus-Based PEC (mg/kg) [a]	ARCS PEL (mg/kg) [b]	Other (mg/kg)		Sediment Screening Benchmark (mg/kg)
Aluminum	--	25,519	--		25,519	--	59,572	--		59,572
Antimony	--	--	2.0	NOAA ERL [c]	2.0	--	--	25.0	NOAA ERM [c]	25.0
Arsenic	9.8	11	--		9.8	33.0	48.0	--		33.0
Barium	--	--	--		no benchmark	--	--	--		no benchmark
Beryllium	--	--	--		no benchmark	--	--	--		no benchmark
Cadmium	0.99	0.58	--		1.0	4.98	3.2	--		5.0
Calcium	--	--	--		no benchmark	--	--	--		no benchmark
Chromium	43	36	--		43	111	120	--		111
Cobalt	--	--	--		no benchmark	--	--	--		no benchmark
Copper	32	28	--		32	149	100	--		149
Cyanide	--	--	--		no benchmark	--	--	--		no benchmark
Iron	--	188,400	--		188,400	--	247,600	--		247,600
Lead	36	37	--		36	128	82.0	--		128
Magnesium	--	--	--		no benchmark	--	--	--		no benchmark
Manganese	--	631	--		631	--	1,184	--		1184
Mercury	0.18	--	--		0.18	1.06	--	--		1.06
Nickel	23	20	--		23	48.6	33	--		49
Potassium	--	--	--		no benchmark	--	--	--		no benchmark
Phosphorus	--	--	--		no benchmark	--	--	--		no benchmark
Selenium	--	--	--		no benchmark	--	--	--		no benchmark
Silver	--	--	1.0	NOAA ERL [c]	1	--	--	3.7	NOAA ERM [c]	4
Sodium	--	--	--		no benchmark	--	--	--		no benchmark
Sulfide	--	--	--		no benchmark	--	--	--		no benchmark
Thallium	--	--	--		no benchmark	--	--	--		no benchmark
Vanadium	--	--	--		no benchmark	--	--	--		no benchmark
Zinc	121	98	--		121	459	540	--		459

Notes:

1 The TEC encompasses several types of sediment quality guidelines including the Lowest Effect Level (LEL), the Threshold Effect Level (TEL), the Effect Range Low (ERL), the TEL for Hyalella azetca in 28 day tests (TEL-HA28), and the Minimum Effect Threshold (MET).

2 The PEC encompasses several types of sediment quality guidelines including the Severe Effect Level (SEL), the Probable Effect Level (TEL), the Effect Range Median (ERM), the PEL for Hyalella azetca in 28 day tests (PEL-HA28), and the Toxic Effect Threshold (TET).

Sources Hierarchy:

a MacDonald et al. (2000); consensus-based threshold effect concentration (TEC) and probable effect concentration (PEC).

b Ingersoll, et al. (1996); Threshold Effect Level (TEL) and Probable Effect Level (PEL) for total extraction of sediment (BT) samples from *Hyalella azteca* 28-day

c Long and Morgan (1990); NOAA Effect Range Low (ERL) and Effect Range Median (ERM).

Table 5-4
Hazard Quotient Range (PEC - TEC) for Benthic Invertebrates from Direct Contact with Bulk Sediment

Analyte	Canyon Ferry Reservoir (Ref)		Lower Lake			Prickly Pear Creek				
						(Ref)	(upstream >>> downstream)			
	CFR 1	CFR 2	LL 1	LL 2	LL 3	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
ALUMINUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
ANTIMONY	ND	ND	40 - 500	10 - 200	20 - 300	R	ND	<1 - 2	<1 - 2	<1 - <1
ARSENIC	<1 - <1	<1 - 2	50 - 200	80 - 300	90 - 300	<1 - <1	2 - 5	4 - 10	8 - 30	<1 - 3
CADMIUM	<1 - <1	<1 - <1	200 - 1000	200 - 1000	500 - 3000	<1 - 4	<1 - 6	5 - 20	7 - 40	<1 - 4
CHROMIUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
COPPER	<1 - <1	<1 - <1	10 - 60	10 - 60	20 - 80	<1 - 2	<1 - 3	<1 - 7	3 - 20	<1 - <1
IRON	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
LEAD	<1 - <1	<1 - <1	70 - 300	70 - 300	100 - 400	<1 - 3	3 - 10	7 - 20	9 - 30	2 - 6
MANGANESE	<1 - <1	<1 - <1	<1 - <1	<1 - 2	<1 - 2	<1 - <1	<1 - <1	3 - 6	8 - 10	<1 - <1
MERCURY	ND	ND	50 - 300	40 - 200	50 - 300	R	<1 - 2	2 - 10	3 - 20	<1 - 2
NICKEL	<1 - <1	<1 - <1	<1 - <1	<1 - 2	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
SILVER	ND	ND	30 - 100	30 - 90	40 - 100	R	ND	<1 - <1	<1 - 2	ND
ZINC	<1 - <1	<1 - <1	10 - 40	10 - 50	20 - 60	<1 - 4	2 - 8	4 - 20	9 - 30	<1 - 4

Analyte	Upper Lake/Marsh Area											
	ULM 1	ULM 2	ULM 3	ULM 4	ULM 5	ULM 6	ULM 7	ULM 8	ULM 9	ULM 10	ULM 11	ULM 12
ALUMINUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
ANTIMONY	<1 - 10	<1 - <1	<1 - 3	<1 - 8	<1 - 5	3 - 30	<1 - <1	<1 - 3	<1 - <1	2 - 30	4 - 60	3 - 30
ARSENIC	7 - 20	4 - 10	5 - 20	4 - 10	4 - 10	10 - 30	2 - 6	9 - 30	4 - 10	10 - 30	20 - 60	10 - 50
CADMIUM	20 - 100	2 - 10	10 - 70	9 - 40	9 - 50	40 - 200	3 - 20	8 - 40	4 - 20	50 - 200	70 - 300	60 - 300
CHROMIUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
COPPER	5 - 20	<1 - 6	3 - 10	3 - 10	2 - 10	9 - 40	<1 - 5	3 - 10	<1 - 6	9 - 40	20 - 70	10 - 60
IRON	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
LEAD	30 - 100	5 - 20	10 - 40	9 - 30	10 - 40	40 - 100	4 - 10	10 - 50	4 - 10	40 - 100	80 - 300	70 - 300
MANGANESE	<1 - <1	2 - 4	<1 - 2	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - 2	<1 - 2
MERCURY	10 - 80	<1 - 3	4 - 30	6 - 30	10 - 80	30 - 200	<1 - 7	10 - 60	2 - 10	30 - 200	50 - 300	60 - 300
NICKEL	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
SILVER	8 - 30	<1 - <1	3 - 10	4 - 10	3 - 10	20 - 60	<1 - 3	4 - 10	ND	20 - 60	30 - 100	30 - 100
ZINC	4 - 10	4 - 10	8 - 30	5 - 20	4 - 10	9 - 30	3 - 10	5 - 20	4 - 10	9 - 40	10 - 50	10 - 50

bold Detected, estimated HQ above a level of concern
PEC = Probable Effect Concentration
TEC = Threshold Effect Concentration
ND = Not Detected
R = Analytical result rejected by validator

Table 5-5
Range of Hazard Quotients (Acute - Chronic) for Benthic Invertebrates from Direct Contact with Sediment Porewater

Analyte	Canyon Ferry Reservoir (Ref)		Lower Lake	Upper Lake/Marsh Area						Prickly Pear Creek				
										(Ref)	(upstream >>> downstream)			
	CFR 1	CFR 2	LL 1	ULM 3	ULM 4	ULM 6	ULM 7	ULM 10	ULM 12	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
ALUMINUM	ND	ND	**<1 - 2**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ANTIMONY	ND	ND	**3 - 20**	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1 - <1	ND
ARSENIC	<1 - <1	<1 - <1	**7 - 20**	ND	ND	ND	ND	ND	ND	ND	ND	<1 - <1	<1 - <1	ND
BARIUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND	ND	<1 - <1	<1 - <1	<1 - <1
BERYLLIUM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHROMIUM	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND	ND	<1 - <1
COBALT	ND	ND	ND	ND	ND	ND	<1 - <1	ND	ND	ND	ND	ND	ND	<1 - <1
IRON	NC - <1	ND	NC - <1	NC - <1	**NC - 2**	NC - <1	**NC - 20**	**NC - 2**	**NC - 5**	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
MANGANESE	**<1 - 2**	**<1 - 3**	**<1 - 6**	**<1 - 8**	**<1 - 20**	**<1 - 20**	**<1 - 20**	**<1 - 30**	**<1 - 20**	**<1 - 8**	**<1 - 5**	ND	ND	**<1 - 10**
MERCURY	--	--	--	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
POTASSIUM	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
SELENIUM	ND	<1 - <1	<1 - <1	ND	ND	ND	ND	ND	ND	ND	ND	**<1 - 2**	**<1 - 2**	**<1 - 3**
SODIUM	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1	NC - <1
THALLIUM	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
VANADIUM	ND	ND	<1 - <1	ND	ND	ND	ND	ND	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
CADMIUM*	ND	ND	**<1 - 8**	ND	ND	ND	<1 - <1	ND	ND	**<1 - 2**	**<1 - 4**	<1 - <1	<1 - <1	**<1 - 5**
COPPER*	<1 - <1	<1 - <1	<1 - <1	<1 - <1	ND	<1 - <1	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
LEAD*	ND	ND	**<1 - 3**	ND	ND	<1 - <1	ND	<1 - <1	**<1 - 2**	ND	ND	ND	ND	ND
NICKEL*	ND	ND	<1 - <1	<1 - <1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SILVER*	<1 - NC	<1 - NC	<1 - NC	<1 - NC	ND	<1 - NC	<1 - NC	<1 - NC	<1 - NC	R	<1 - NC	<1 - NC	<1 - NC	<1 - NC
ZINC*	ND	ND	<1 - <1	ND	ND	ND	ND	<1 - <1	ND	<1 - <1	<1 - <1	<1 - <1	<1 - <1	<1 - <1
Hardness (mg/L)	*227*	*232*	*193*	*182*	*154*	*229*	*290*	*196*	*222*	*51*	*118*	*116*	*118*	*212*

bold Detected, estimated HQ above a level of concern
ND = Not Detected
NC = Not Calculated, no benchmark available
R = Analytical result rejected by validator
-- = Not Analyzed
* Acute and chronic benchmarks for these metals are hardness-dependant, and were calculated based on the sample-specific hardness.

Table 5-6
Sediment Toxicity Test Results for *Hyalella azteca*

Exposure Area	Station ID	Replicate[a]	# Surviving Organisms	Average Survival (%)	Survival t-test p value[b]	Biomass (ug)	Average Biomass (ug)	Biomass t-test p value[b]
Laboratory Control		A	10	92.5%	--	0.16	0.160	--
		B	10			0.15		
		C	9			0.156		
		D	8			0.175		
Canyon Ferry Reservoir (Ref)	CFR_1	A	9	95.0%	0.67	0.156	0.148	0.18
		B	10			0.15		
		C	9			0.156		
		D	10			0.13		
	CFR_2	A	10	90.0%	0.75	0.160	0.160	0.98
		B	8			0.200		
		C	10			0.090		
		D	8			0.188		
Lower Lake	LL_1	A	7	75.0%	0.07	0.2	0.174	0.45
		B	6			0.2		
		C	9			0.144		
		D	8			0.15		
Upper Lake/Marsh Area	ULM_6	A	10	95.0%	0.73	0.2	0.171	0.61
		B	8			0.163		
		C	10			0.2		
		D	10			0.12		
	ULM_4	A	10	97.5%	0.39	0.25	0.201	0.21
		B	9			0.122		
		C	10			0.23		
		D	10			0.2		
	ULM_12	A	10	97.5%	0.39	0.33	0.247	0.040
		B	10			0.27		
		C	9			0.189		
		D	10			0.2		
	ULM_10	A	10	97.5%	0.39	0.230	0.220	0.0013
		B	10			0.210		
		C	10			0.240		
		D	9			0.200		
	ULM_7	A	10	95.0%	0.67	0.21	0.242	0.0024
		B	10			0.27		
		C	9			0.222		
		D	9			0.267		
	ULM_3	A	10	90.0%	0.75	0.38	0.278	0.015
		B	8			0.25		
		C	8			0.25		
		D	10			0.23		

[a] N = 10 organisms per replicate

[b] p-value compared to laboratory control

Statistically significant decrease compared to laboratory control.

Table 5-7
Comparison of Measured Concentrations in Aquatic Food Items to Oral Toxicity Benchmarks for Fish

Part A: Screening-Level Oral Toxicity Benchmark Values for Fish (mg/kg dw)

Metal	Threshold Oral Benchmark[1]	NOAEL Oral Benchmark[2]	LOAEL Oral Benchmark[2]
Arsenic	40	63	137
Cadmium	--	55	165
Copper	--	340	660
Lead	--	170	510
Selenium	--	--	--
Zinc	--	1500	4500

NOAEL = no observed adverse effect level
LOAEL = lowest observed adverse effect level
[1] Benchmark Source: USEPA (2004d)
[2] Benchmark Source: Ecological Risk Assessment for the Clark Fork River, Montana (USEPA, 2001)

Part B: Upper Lake/Marsh Area and Canyon Ferry Reservoir

Metal	Aquatic Invertebrates (mg/kg dw*)			Trout Stomach Contents (mg/kg dw*)			
	Canyon Ferry (Ref)	Upper Lake/ Marsh Area		Canyon Ferry (Ref)	Upper Lake/ Marsh Area		
	CFR 2	ULM 1	ULM 10		ULM 11	ULM 3	UL
Arsenic	10 U	10 U	10 U	--	10 U	10 U	15
Cadmium	1.0	4.0	48	--	2.0	2.0	48
Copper	50	156.5	397.5	--	46	36	92.5
Lead	20.5	59.5	525.5	--	15.5	17	799
Selenium	25 U	25 U	25 U	--	25 U	25 U	25 U
Zinc	85	140	335	--	320	255	940

Data Source: USEPA 2003 Ecological Field Investigation
* Concentrations converted from wet weight to dry weight assuming 20% solids.

higher than reference
higher than toxicity benchmark(s)

Part C: Prickly Pear Creek - Above and Below the East Helena Site

Metal	Invertebrate Composite (mg/kg dw)						Stonefly Larvae (mg/kg dw)					
	Upstream (N = 4)			Downstream (N = 6)			Upstream (N = 3)			Downstream (N = 4)		
	geomean	min	max	geomean	min	max	geomean	min	max	geomean	min	max
Arsenic	15.9	7.78	21.7	19.2	10.5	30.3	7.4	2.59	13.3	16.9	11	26.3
Cadmium	2.74	2.04	3.23	6.31	1.58	20.4	2.58	1.23	8.61	4.8	3.22	7.42
Copper	79.9	41.7	133	130.1	93.2	196	44.8	42.9	46.9	72.4	55.2	99.4
Lead	35.1	17.5	83.5	47.7	17.8	82.4	24.8	26.1	45.4	68.5	38.6	111
Zinc	336	197	464	247	97	436	356	310	418	480	338	661

Data Source: USFWS (1997) - Table 3

significantly higher than upstream (Mann-Whitney U-test, $p < 0.05$)
higher than toxicity benchmark(s)

Table 5-8
Comparison of Measured Bulk Sediment Concentrations to Oral Toxicity Benchmarks for Fish

Part A: Screening-Level Oral Toxicity Benchmark Values for Fish (mg/kg dw)

	Oral Benchmarks for Dietary Exposures			Oral Benchmarks for Sediment Exposures[3]		
Analyte	Threshold[1]	NOAEL[2]	LOAEL[2]	Threshold	NOAEL	LOAEL
Arsenic	40	63	137	1,600	2,520	5,480
Cadmium	--	55	165	--	2,200	6,600
Copper	--	340	660	--	13,600	26,400
Lead	--	170	510	--	6,800	20,400
Zinc	--	1,500	4,500	--	60,000	180,000

NOAEL = no observed adverse effect level

LOAEL = lowest observed adverse effect level

[1] Benchmark Source: USEPA (2004d)

[2] Benchmark Source: Ecological Risk Assessment for the Clark Fork River, Montana (USEPA, 2001

[3] Assumes that the fraction of the diet that is sediment is 5% with a relative bioavailability of 50%

Part B: Measured Bulk Sediment Concentrations (mg/kg)

	Canyon Ferry Reservoir (Ref)		Lower Lake			Prickly Pear Creek				
						(Ref)	(upstream >>> downstream)			
Analyte	CFR 1	CFR 2	LL 1	LL 2	LL 3	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
Arsenic	12.4	15.6	**1,660**	**2,730**	**3,030**	11.5	52.1	122	250	32.1
Cadmium	0.97	1.2	1,230	1,150	**2,680**	3.5	6	22.8	36.8	4.1
Copper	28.1	33.6	1,920	1,900	2,600	59.7	93.9	221	480	44.1
Lead	17.2	23.5	**9,470**	**9,420**	**14,400**	104	370	878	1,090	203
Zinc	81.4	102	4,490	6,080	6,930	454	925	1,860	3,930	444

	Upper Lake/Marsh Area											
Analyte	ULM 1	ULM 2	ULM 3	ULM 4	ULM 5	ULM 6	ULM 7	ULM 8	ULM 9	ULM 10	ULM 11	ULM 12
Arsenic	229	121	162	116	124	326	54.6	297	146	337	581	452
Cadmium	112	12.2	66.9	42.5	46.6	199	15	38.3	17.7	238	338	316
Copper	686	191	430	404	332	1,270	158	391	180	1,310	2,290	1,970
Lead	4,270	594	1,470	1,170	1,610	5,360	486	1850	529	5,140	**10,400**	**8,990**
Zinc	1,810	1,680	3,540	2,100	1,680	4,200	1,360	2,120	1,670	4,260	6,550	6,420

U = Not detected, detection limit shown

R = Analytical result was rejected by validator

[shaded] higher than toxicity benchmark for sediment exposures

Table 5-9
Tissue Burden-Based Toxicity Benchmarks for Fish and Aquatic Invertebrates

PART A: FISH

Metal	Fish					
	NEL_{high} (ug/g ww)	EL_{low} (ug/g ww)	Tissue Type	Effect Type	EL Species	Data Summary
Arsenic	2	3	Whole body	GRO, MOR	Rainbow trout	N=19 NELs; N=33 ELs
Cadmium	0.11	0.12	Whole body	GRO	Atlantic salmon	N=29 NELs; N=23 ELs
	0.38	0.64	Kidney	MOR	Threespine stickleback	N=24 NELs; N=17 ELs
	1.6	1.8	Liver	GRO	Brook trout	N=24 NELs; N=16 ELs
	0.10	0.12	Muscle	GRO	Rainbow trout	N=11 NELs; N=5 ELs
Copper	10.56	11.1	Whole body	MOR	Common carp	N=3 NELs; N=3 ELs
	--	1.5	Kidney	GRO	Coho salmon	N=16 NELs; N=7 ELs
	1.00	1.84	Liver	GRO	Channel catfish	N=22 NELs; N=12 ELs
	0.28	0.3	Muscle	GRO	Channel catfish	N=8 NELs; N=3 ELs
Lead	0.34	0.40	Whole body	REP (Hatch success)	Brook trout	N=2 NELs; N=2 ELs
	35.0	65.2	Kidney	GRO, REP, MOR	Brook trout	N=7 NELs; N=3 ELs
	20.0	26.8	Liver	MOR	Brook trout	N=22 NELs; N=12 ELs
Mercury	--	0.04	Whole body	MOR	Rainbow trout	N=33 NELs; N=26 ELs
	1.6	2.9	Edible tissue	MOR	Rainbow trout	N=3 NELs; N=1 ELs
Selenium	0.60	0.66	Whole body	GRO	Chinook salmon	N=27 NELs; N=17 ELs
	1.81	1.92	Kidney	GRO	Rainbow trout	N=16 NELs; N=5 ELs
	7.70	8.84	Liver	GRO	Rainbow trout	N=16 NELs; N=6 ELs
	1.9	3.8	Muscle	MOR	Striped bass	N=16 NELs; N=6 ELs
Zinc	34	40	Whole body	GRO	American flagfish	N=14 NELs; N=4 ELs
	--	36.9	Kidney	REP (Hatch success)	Brook trout	N=5 NELs; N=1 EL
	60	66.3	Liver	REP (Hatch success)	Brook trout	N=8 NELs; N=1 EL

PART B: AQUATIC INVERTEBRATES

Metal	Aquatic Invertebrates					
	NEL_{high} (ug/g ww)	EL_{low} (ug/g ww)	Tissue Type	Effect Type	EL Species	Data Summary
Arsenic	--	--				N = 0
Cadmium	2.6	3.5	Whole body	MOR	Daphnia	N=35 NELs; N=40 ELs
Copper	3.4	4.4	Whole body	REP	Hydra	N=4 NELs; N=8 ELs
Lead	--	98	Whole body	MOR	Gammarus	N=3 NELs; N=1 ELs
Selenium	--	0.22	Whole body	GRO, MOR	Daphnia	N=16 NELs; N=13 ELs
Zinc	12.7	35.2	Whole body	MOR	Crayfish	N=5 NELs; N=5 ELs

Source: Jarvinen and Ankley (1999)

NEL_{high} = tissue concentration for the highest No Effect Level below the lowest Effect Level
EL_{low} = tissue concentration for the lowest Effect Level above the highest No Effect Level

GRO = growth
REP = reproduction
MOR = mortality/survival

Table 5-10a
Comparison of Measured Tissue Burdens in the Upper Lake/Marsh Area to Tissue-Based Toxicity Benchmarks

Media: Aquatic Invertebrates (mg/kg ww)

Analyte	Canyon Ferry (Ref)	Upper Lake/ Marsh Area	
	CFR 2	ULM 1	ULM 10
Arsenic	2 U	2 U	2 U
Cadmium	0.2	0.8	**9.6**
Copper	**10**	**31.3**	**79.5**
Lead	4.1	11.9	**105.1**
Selenium	**5 U**	**5 U**	**5 U**
Zinc	**17**	**28**	**67**

Media: Fish (mg/kg ww)

Analyte	Canyon Ferry (Ref)		Upper Lake/ Marsh Area					
	Forage	Organ-Specific	Forage	RBT Kidney	RBT Liver	RBT Fillet	RBT Fillet	RBT Wh. Body
Arsenic	2 U	--	2 U	2 U	2 U	2 U	2 U	--
Cadmium	**0.2 U**	--	**1.4**	0.2 U	0.9	**0.2**	**0.2 U**	--
Copper	2.1	--	9.1	**2.1**	**140.1**	**1.6**	**1.3**	--
Lead	**0.8 U**	--	**25**	0.8 U	1.3	0.8 U	0.8 U	--
Mercury	**0.025**	--	**0.065**	--	--	0.217		**0.106**
Selenium	**5 U**	--	**5 U**	**5 U**	**12**	**5 U**	**5 U**	--
Zinc	**35**	--	**66**	**35**	51	13	5	--

RBT = rainbow trout
-- = not analyzed

Media: Aquatic Plants/Algae (mg/kg ww)

Analyte	Canyon Ferry (Ref)	Upper Lake/Marsh Area							
	CFR 1	ULM 1	ULM 11	ULM 2	ULM 5	ULM 8	ULM 9	UL comp.	UL comp.
Arsenic	2 U	2 U	4	11	4	15	17	11	3
Cadmium	0.6	0.4	1.2	0.9	1.4	2.6	4.2	1.5	1.8
Copper	5.8	1.7	8.4	6.3	14.3	7.4	18.8	10.4	4.9
Lead	11.4	3	37.8	10.4	50	13.4	41.8	21.2	29.4
Selenium	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Zinc	18	8	35	51	73	63	94	45	46

[box] higher than reference
bold higher than the NEL_{high} (see Table 5-8)

Table 5-10b
Comparison of Measured Tissue Burdens in Prickly Pear Creek to Tissue-Based Toxicity Benchmarks

Metal	Invertebrate Composite (ug/g ww)				Stonefly Larvae (ug/g ww)			
	Upstream (N = 4)		Downstream (N = 6)		Upstream (N = 3)		Downstream (N = 4)	
	geomean	min - max	geomean	min - max	geomean	min - max	geomean	min - max
Arsenic	3.18	1.556 - 4.34	3.84	2.1 - 6.06	1.48	0.518 - 2.66	3.38	2.2 - 5.26
Cadmium	0.548	0.408 - 0.646	1.262	0.316 - **4.08**	0.516	0.246 - 1.722	0.96	0.644 - 1.484
Copper	**16.0**	**8.3 - 26.6**	**26.0**	**18.6 - 39.2**	**9.0**	**8.6 - 9.4**	**14.5**	**11.0 - 19.9**
Lead	7.02	3.5 - 16.7	9.54	3.56 - 16.48	4.96	5.22 - 9.08	13.7	7.72 - 22.2
Zinc	**67.2**	**39.4 - 92.8**	**49.4**	**19.4 - 87.2**	**71.2**	**62.0 - 83.6**	**96.0**	**67.6 - 132.2**

Source: USFWS (1997) - Table 3
Converted from dry weight to wet wight assuming 20% solids.

Metal	Rainbow Trout (ug/g ww)				Brook Trout (ug/g ww).			
	Upstream (N = 4)		Downstream (N = 5)		Upstream (N = 3)		Downstream (N = 3)	
	geomean	min - max	geomean	min - max	geomean	min - max	geomean	min - max
Arsenic	0.405	0.27 - 0.763	0.408	0.143 - 0.968	0.245	0.148 - 0.315	NC	<0.125 - 0.258
Cadmium	**0.118**	0.07 - **0.32**	**0.263**	0.080 - **1.135**	0.08	0.045 - **0.112**	0.095	0.068 - **0.149**
Copper	4.28	2.50 - 7.475	2.48	1.25 - 3.98	3.80	2.36 - 5.43	4.3	3.45 - 6.68
Lead	**0.72**	0.182 - **3.275**	**0.755**	0.132 - **6.4**	0.275	<0.126 - **0.605**	0.115	<0.126 - 0.181
Zinc	**35.0**	28.5 - **47.25**	**37.8**	25.8 - **56.3**	**49.5**	**45.0 - 55.5**	**39.0**	26.3 - **54.3**

Source: USFWS (1997) - Table 4
NC = Not Calculated
Converted from dry weight to wet wight assuming 25% solids.

Metal	Brown Trout (ug/g ww)				Rainbow Trout (ug/g ww)				White Sucker (ug/g ww)	
	Upstream (N = 3)		Downstream (N = 3)		Upstream (N = 3)		Downstream (N = 3)		Upstream	Downstream
	geomean	min - max	geomean	min - max	geomean	min - max	geomean	min - max	(N = 1)	(N = 1)
Mercury	**0.038**	**<0.025 - 0.054**	NC	**<0.0251 - <0.0255**	NC	**<0.0253 - 0.032**	NC	**<0.0251 - <0.0253**	**0.0478**	**<0.0254**

Source: USFWS (1997) - Addendum
NC = Not Calculated
Converted from dry weight to wet wight assuming 25% solids.

[boxed cell] significantly higher than upstream (Mann-Whitney U-test, $p < 0.05$)
bold higher than the NEL_{high} (see Table 5-8)

Table 6-1
Exposure Factors for Representative Wildlife Species

Receptor Class/Type		Surrogate Receptor	Body Weight (kg)	Food Ingestion Rate (kg wet weight/day)	Water Ingestion Rate (L/day)	Sediment Ingestion Rate (kg dry weight/day)	Home Range Size	Dietary Fraction (df)		
								Fish	Aquatic Invert.	Aquatic Plants
Bird	Omnivore	Mallard Duck	1.13	0.316	0.064	0.004	110 ha		0.75	0.25
Bird	Piscivore	Belted Kingfisher	0.147	0.073	0.016	0.0002	1.4 km (foraging distance)	1.00		
Bird	Insectivore	Cliff Swallow	0.023	0.013	0.005	0.00035	< 6 km (foraging radius)		1.00	
Mammal	Piscivore	Mink	0.556	0.089	0.058	0.0002	14 ha	1.00		

See Appendix E for detailed exposure factor and source information.

Table 6-2
Exposure Point Concentrations (EPCs) Used to Evaluate Potential Risks to Wildlife
EPCs Based on Maximum Detected Concentrations

Work Area	Analyte	Exposure Point Concentrations (EPCs)				
		Surface Water	Sediment	Fish	Aquatic Invert.	Aquatic Plants
		mg/L	mg/kg dw	mg/kg ww	mg/kg ww	mg/kg ww
Lower Lake	Antimony	0.44	1000	na	na	na
	Arsenic	0.24	3000	na	na	na
	Barium	0.044	240	na	na	na
	Beryllium	ND	1.8	na	na	na
	Cadmium	0.0089	2700	na	na	na
	Chromium	0.001	22	na	na	na
	Cobalt	ND	35	na	na	na
	Copper	0.032	2600	na	na	na
	Lead	0.087	14000	na	na	na
	Manganese	0.22	1400	na	na	na
	Mercury	0.00022	53	na	na	na
	Nickel	0.0043	36	na	na	na
	Selenium	0.054	430	na	na	na
	Silver	0.0021	140	na	na	na
	Thallium	0.068	2000	na	na	na
	Vanadium	ND	58	na	na	na
	Zinc	0.12	6900	na	na	na
Upper Lake/Marsh Area	Antimony	ND	110	na	na	na
	Arsenic	0.032	580	ND	ND	17
	Barium	0.064	280	na	na	na
	Beryllium	ND	2.1	na	na	na
	Cadmium	0.0056	340	1.4	10	4.2
	Chromium	0.0041	27	na	na	na
	Cobalt	0.0027	24	na	na	na
	Copper	0.028	2300	9.1	80	19
	Lead	0.16	10000	25	110	50
	Manganese	2.2	2500	na	na	na
	Mercury	0.00074	59	0.11	na	na
	Nickel	ND	25	na	na	na
	Selenium	ND	20	ND	ND	ND
	Silver	0.00094	130	na	na	na
	Thallium	ND	4.8	na	na	na
	Vanadium	0.0056	59	na	na	na
	Zinc	0.25	6600	66	67	94
Canyon Ferry Reservoir	Antimony	0.0069	ND	na	na	na
	Arsenic	0.015	16	ND	ND	ND
	Barium	0.12	180	na	na	na
	Beryllium	0.00052	1.8	na	na	na
	Cadmium	0.00052	1.2	ND	0.2	0.6
	Chromium	0.0065	24	na	na	na
	Cobalt	0.0022	9.3	na	na	na
	Copper	0.011	34	2.1	10	5.8
	Lead	0.015	24	ND	4.1	11
	Manganese	0.064	260	na	na	na
	Mercury	ND	ND	0.029	na	na
	Nickel	0.0057	19	na	na	na
	Selenium	0.014	ND	ND	ND	ND
	Silver	0.00081	ND	na	na	na
	Thallium	ND	ND	na	na	na
	Vanadium	0.016	28	na	na	na
	Zinc	0.12	100	35	17	18

Table 6-2 (continued)
Exposure Point Concentrations (EPCs) Used to Evaluate Potential Risks to Wildlife
EPCs Based on Maximum Detected Concentrations

Work Area	Analyte	Exposure Point Concentrations (EPCs)				
		Surface Water	Sediment	Fish	Aquatic Invert.	Aquatic Plants
		mg/L	mg/kg dw	mg/kg ww	mg/kg ww	mg/kg ww
Prickly Pear Creek	Antimony	ND	4.5	na	na	na
	Arsenic	0.012	250	1.0	6.1	61
	Barium	0.05	350	na	na	na
	Beryllium	ND	1.4	na	na	na
	Cadmium	0.00036	37	1.1	4.1	4.1
	Chromium	ND	21	na	na	na
	Cobalt	ND	21	na	na	na
	Copper	0.005	480	6.7	39	39
	Lead	0.0049	1100	6.4	22	22
	Manganese	0.089	9000	na	na	na
	Mercury	ND	3.1	0.054	na	na
	Nickel	ND	16	na	na	na
	Selenium	ND	5.3	na	na	na
	Silver	ND	2.5	na	na	na
	Thallium	ND	ND	na	na	na
	Vanadium	ND	55	na	na	na
	Zinc	0.095	3900	56	130	130
Prickly Pear Creek (upstream)	Antimony	0.011	na	na	na	na
	Arsenic	ND	12	0.76	4.3	22
	Barium	ND	110	na	na	na
	Beryllium	ND	0.91	na	na	na
	Cadmium	ND	3.5	0.32	1.7	1.7
	Chromium	ND	18	na	na	na
	Cobalt	ND	10	na	na	na
	Copper	0.0045	60	7.5	27	27
	Lead	ND	100	3.3	17	17
	Manganese	0.02	720	na	na	na
	Mercury	ND	na	ND	na	na
	Nickel	ND	10	na	na	na
	Selenium	ND	na	na	na	na
	Silver	ND	na	na	na	na
	Thallium	ND	na	na	na	na
	Vanadium	ND	40	na	na	na
	Zinc	0.081	450	56	93	93

na = not available
ND = not detected

(shaded) provided by USFWS (1997); converted from dry weight to wet weight assuming 25% solids for fish and 20% solids for aquatic invertebrates.

Table 6-3
Summary of Selected Wildlife Toxicity Reference Values (TRVs)

Analyte	Toxicity Reference Values (mg/kg BW/day)					
	Mammals			Birds		
	Low TRV/ NOAEL	High TRV/ LOAEL	Source	Low TRV/ NOAEL	High TRV/ LOAEL	Source
Aluminum	narrative statement [a]		1	narrative statement [a]		1
Antimony	0.059	--	1	no TRV	no TRV	
Arsenic	0.32	4.7	2	5.5	22	2
Barium	51.8	--	1	21	42	3
Beryllium	0.532	--	1	no TRV	no TRV	
Cadmium	0.77	--	1	1.47	--	1
Chromium	3.3	13.1	3 [b]	1.0	5.0	3 [b]
Cobalt	7.34	--	1	7.61	--	1
Copper	2.7	632	2	2.3	52	2
Lead	4.7	--	1	1.63	--	1
Manganese	14	159	2	78	776	2
Mercury, Inorganic	1.4	6.9	3	0.45	0.90	3
Mercury, Organic	0.25	4.0	2	0.039	0.180	2
Nickel	0.13	32	2	1.4	56	2
Selenium	0.05	1.21	2	0.23	0.93	2
Silver	no TRV	no TRV		no TRV	no TRV	
Thallium	0.48	1.43	2	no TRV	no TRV	
Vanadium	0.21	2.1	3	11.4	no TRV	3
Zinc	10	411	2	17	172	2

See Appendix B for details on the selected TRV.

[a] Aluminum is expected to be a contaminant of potential concern only when pH is below 5.5.

[b] The mammalian TRV is based on Cr^{6+} (the lower of the Cr^{3+} and Cr^{6+} values).
The bird TRV is based on Cr3+ (insufficient toxicity data for birds to derive a TRV for Cr^{6+}).

Source:
1 -- USEPA Eco-SSL (2003b)
2 -- Engineering Field Activity West (1998)
3 -- Sample et al. (1996)

Table 6-4
Estimated Risks to the Mallard Duck from Ingestion of Contaminated Media
Based on NOAEL TRVs

Analyte	Total HQs and Exposure Pathways Evaluated Quantitatively[1]									
	Lower Lake		Upper Lake/ Marsh Area		Canyon Ferry Reservoir (ref)		Prickly Pear Creek		Prickly Pear Creek (upstream ref)	
Antimony	No TRV		No TRV		No TRV		No TRV		No TRV	
Arsenic	**1.9**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	**1.2**	(w,s,f)	<1	(w,s,f)
Barium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Beryllium	No TRV		No TRV		No TRV		No TRV		No TRV	
Cadmium	**6.2**	(w,s,f)	**2.4**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)
Chromium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Cobalt	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Copper	**3.8**	(w,s,f)	**11**	(w,s,f)	**1.1**	(w,s,f)	**5.4**	(w,s,f)	**3.4**	(w,s,f)
Lead	**29**	(w,s,f)	**37**	(w,s,f)	1	(w,s,f)	**6.1**	(w,s,f)	**3.1**	(w,s,f)
Manganese	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Mercury	<1	(w,s)	<1	(w,s)	NC	(w,s)	<1	(w,s)	NC	(w,s)
Nickel	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Selenium	**6.4**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	NC	(w,s,f)
Silver	No TRV		No TRV		No TRV		No TRV		No TRV	
Thallium	No TRV		No TRV		No TRV		No TRV		No TRV	
Vanadium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Zinc	**1.4**	(w,s,f)	**2.5**	(w,s,f)	<1	(w,s,f)	**2.9**	(w,s,f)	**1.6**	(w,s,f)

No TRV = inadequate toxicity data to derive a TRV
NC = HQ not calculated; chemical below detection limits in all measured media

Total HQ values greater than 1 are presented to two significant figures.

[1] Exposure pathways evaluated based on measured data:
w = surface water ingestion
s = sediment ingestion
f = food ingestion

Table 6-5
Estimated Risks to the Belted Kingfisher from Ingestion of Contaminated Media
Based on NOAEL TRVs

Analyte	Total HQs and Exposure Pathways Evaluated Quantitatively[1]									
	Lower Lake		Upper Lake/ Marsh Area		Canyon Ferry Reservoir (ref)		Prickly Pear Creek		Prickly Pear Creek (upstream ref)	
Antimony	No TRV		No TRV		No TRV		No TRV		No TRV	
Arsenic	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)
Barium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Beryllium	No TRV		No TRV		No TRV		No TRV		No TRV	
Cadmium	**2.5**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)
Chromium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Cobalt	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Copper	**1.5**	(w,s,f)	**3.3**	(w,s,f)	<1	(w,s,f)	**1.7**	(w,s,f)	**1.7**	(w,s,f)
Lead	**12**	(w,s,f)	**16**	(w,s,f)	<1	(w,s,f)	**2.9**	(w,s,f)	**1.1**	(w,s,f)
Manganese	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Mercury	<1	(w,s)	**1.6**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	NC	(w,s,f)
Nickel	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Selenium	**2.5**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	NC	(w,s,f)
Silver	No TRV		No TRV		No TRV		No TRV		No TRV	
Thallium	No TRV		No TRV		No TRV		No TRV		No TRV	
Vanadium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Zinc	<1	(w,s,f)	**2.4**	(w,s,f)	1	(w,s,f)	**1.9**	(w,s,f)	**1.7**	(w,s,f)

No TRV = inadequate toxicity data to derive a TRV
NC = HQ not calculated; chemical below detection limits in all measured media

Total HQ values greater than 1 are presented to two significant figures.

[1] Exposure pathways evaluated based on measured data:
w = surface water ingestion
s = sediment ingestion
f = food ingestion

Wildlife Risk Calcs_wFWS v3.xls, Total HQ Summ
1/25/2005

Table 6-6
Estimated Risks to the Cliff Swallow from Ingestion of Contaminated Media
Based on NOAEL TRVs

Analyte	Total HQs and Exposure Pathways Evaluated Quantitatively[1]									
	Lower Lake		Upper Lake/ Marsh Area		Canyon Ferry Reservoir (ref)		Prickly Pear Creek		Prickly Pear Creek (upstream ref)	
Antimony	No TRV		No TRV		No TRV		No TRV		No TRV	
Arsenic	8.3	(w,s,f)	1.6	(w,s,f)	<1	(w,s,f)	1.3	(w,s,f)	<1	(w,s,f)
Barium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Beryllium	No TRV		No TRV		No TRV		No TRV		No TRV	
Cadmium	28	(w,s,f)	7.2	(w,s,f)	<1	(w,s,f)	1.9	(w,s,f)	<1	(w,s,f)
Chromium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Cobalt	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Copper	17	(w,s,f)	34	(w,s,f)	2.6	(w,s,f)	12	(w,s,f)	6.7	(w,s,f)
Lead	130	(w,s,f)	130	(w,s,f)	1.6	(w,s,f)	18	(w,s,f)	6.6	(w,s,f)
Manganese	<1	(w,s)	<1	(w,s)	<1	(w,s)	1.8	(w,s)	<1	(w,s)
Mercury	1.8	(w,s)	2	(w,s)	NC	(w,s)	<1	(w,s)	NC	(w,s)
Nickel	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Selenium	28	(w,s,f)	1.3	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	NC	(w,s,f)
Silver	No TRV		No TRV		No TRV		No TRV		No TRV	
Thallium	No TRV		No TRV		No TRV		No TRV		No TRV	
Vanadium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Zinc	6.1	(w,s,f)	7.9	(w,s,f)	<1	(w,s,f)	7.5	(w,s,f)	3.3	(w,s,f)

No TRV = inadequate toxicity data to derive a TRV
NC = HQ not calculated; chemical below detection limits in all measured media

Total HQ values greater than 1 are presented to two significant figures.

[1] Exposure pathways evaluated based on measured data:
w = surface water ingestion
s = sediment ingestion
f = food ingestion

Table 6-6

Estimated Risks to the Cliff Swallow from Ingestion of Contaminated Media

Based on NOAEL TRVs

Analyte	Total HQs and Exposure Pathways Evaluated Quantitatively[1]									
	Lower Lake		Upper Lake/ Marsh Area		Canyon Ferry Reservoir (ref)		Prickly Pear Creek		Prickly Pear Creek (upstream ref)	
Antimony	No TRV		No TRV		No TRV		No TRV		No TRV	
Arsenic	8.3	(w,s,f)	1.6	(w,s,f)	<1	(w,s,f)	1.3	(w,s,f)	<1	(w,s,f)
Barium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Beryllium	No TRV		No TRV		No TRV		No TRV		No TRV	
Cadmium	28	(w,s,f)	7.2	(w,s,f)	<1	(w,s,f)	1.9	(w,s,f)	<1	(w,s,f)
Chromium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Cobalt	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Copper	17	(w,s,f)	34	(w,s,f)	2.6	(w,s,f)	12	(w,s,f)	6.7	(w,s,f)
Lead	130	(w,s,f)	130	(w,s,f)	1.6	(w,s,f)	18	(w,s,f)	6.6	(w,s,f)
Manganese	<1	(w,s)	<1	(w,s)	<1	(w,s)	1.8	(w,s)	<1	(w,s)
Mercury	1.8	(w,s)	2	(w,s)	NC	(w,s)	<1	(w,s)	NC	(w,s)
Nickel	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Selenium	28	(w,s,f)	1.3	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	NC	(w,s,f)
Silver	No TRV		No TRV		No TRV		No TRV		No TRV	
Thallium	No TRV		No TRV		No TRV		No TRV		No TRV	
Vanadium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Zinc	6.1	(w,s,f)	7.9	(w,s,f)	<1	(w,s,f)	7.5	(w,s,f)	3.3	(w,s,f)

No TRV = inadequate toxicity data to derive a TRV

NC = HQ not calculated; chemical below detection limits in all measured media

Total HQ values greater than 1 are presented to two significant figures.

[1] Exposure pathways evaluated based on measured data:
- w = surface water ingestion
- s = sediment ingestion
- f = food ingestion

Table 6-7
Estimated Risks to the Mink from Ingestion of Contaminated Media
Based on NOAEL TRVs

Analyte	**Total HQs and Exposure Pathways Evaluated Quantitatively[1]**									
	Lower Lake		**Upper Lake/ Marsh Area**		**Canyon Ferry Reservoir (ref)**		**Prickly Pear Creek**		**Prickly Pear Creek (upstream ref)**	
Antimony	**7.6**	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Arsenic	**3.8**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)
Barium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Beryllium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Cadmium	**1.4**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)
Chromium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Cobalt	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Copper	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)
Lead	**1.2**	(w,s,f)	**1.7**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)
Manganese	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Mercury	<1	(w,s)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	NC	(w,s,f)
Nickel	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Selenium	**3.6**	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	<1	(w,s,f)	NC	(w,s,f)
Silver	No TRV		No TRV		No TRV		No TRV		No TRV	
Thallium	**1.7**	(w,s)	<1	(w,s)	NC	(w,s)	NC	(w,s)	NC	(w,s)
Vanadium	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)	<1	(w,s)
Zinc	<1	(w,s,f)	**1.4**	(w,s,f)	<1	(w,s,f)	**1.1**	(w,s,f)	<1	(w,s,f)

No TRV = inadequate toxicity data to derive a TRV
NC = HQ not calculated; chemical below detection limits in all measured media

Total HQ values greater than 1 are presented to two significant figures.

[1] Exposure pathways evaluated based on measured data:
- w = surface water ingestion
- s = sediment ingestion
- f = food ingestion

Table 6-8
Primary Drivers of Predicted Risks in Wildlife

Receptor Class: Surrogate Species	Metals of Concern [a] (range of Total HQs > 1)	Exposure Areas of Concern[b]	Primary Risk Drivers: **Onsite Lakes & Marsh Areas**			Primary Risk Drivers: **Prickly Pear Creek**		
			Dietary Items[c]	Sediment	Surface Water	Dietary Items	Sediment	Surface Water
Waterfowl: Mallard	lead (6.1 - 37)	ULM, LL, PPC	○	●		●	○	
	copper (3.8 - 11)	ULM, PPC, LL	●	○		●		
	cadmium (2.4 - 6.2)	LL, ULM[d]	○	●				
	selenium (6.4)	LL		●				
	zinc (1.4 - 2.9)	PPC, ULM, LL	○	●		●		
	arsenic (1.2-1.9)	LL, PPC[e]		●				
Piscivorous birds: Belted Kingfisher	lead (2.9 - 16)	ULM, LL, PPC	○	●		●		
	copper (1.5 - 3.3)	ULM, LL	●	○				
	cadmium (2.5)	LL		●				
	zinc (2.4)	ULM	●					
	selenium (2.5)	LL		●				
	mercury (1.6)	ULM	●					
Insectivorous birds: Cliff Swallow	lead (18 - 130)	LL, ULM, PPC	○	●		○	●	
	copper (12 - 34)	ULM, LL, PPC	●	○		●	○	
	cadmium (1.9 - 28)	LL, ULM[d], PPC	○	●		●		
	selenium (1.3 - 28)	LL, ULM		●				
	arsenic (1.3 - 8.3)	LL, ULM, PPC[e]		●				
	zinc (6.1 - 7.9)	ULM, PPC, LL	○	●		●	○	
	mercury (1.8 - 2.0)	ULM, LL	f	●				
	manganese (1.8)	PPC					●	
Piscivorous mammals: Mink	antimony (7.6)	LL	f	●				
	arsenic (3.8)	LL		●				
	selenium (3.6)	LL		●				
	lead (1.2 - 1.7)	ULM[e], LL		●				
	thallium (1.7)	LL	f	●				
	zinc (1.1 - 1.4)	ULM, PPC[e]	●					
	cadmium (1.4)	LL		●				

● = Primary contributor
○ = Secondary contributor

[a] Relative to reference areas

[b] Presented in order from highest to lowest predicted risks
Exposure Areas: LL = Lower Lake; ULM = Upper Lake/Marsh Area, PPC = Prickly Pear Creek

[c] Exposures from dietary items could not be evaluated for Lower Lake because measured data were not available

[d] Food item ingestion tended to contribute more than sediment ingestion

[e] All individual exposure pathway HQs were < 1

[f] Exposures from dietary items could not be evaluated for Upper Lake and marsh area because measured data were not available

Table 7-1
Chemicals with Inadequate Detection Limits or Without Toxicity Benchmarks

PANEL A: Chemicals with Inadequate Detection Limits (DLs)

Receptor	Exposure Pathway	Analyte	Benchmark Exceeded	Benchmark Value	DLs of Exceedances	Frequency of DLs > Benchmark by Exposure Area
Aquatic Community (Fish & Benthic Invertebrates)	Direct Contact with Surface Water	beryllium	GLWQI Tier II SCV	0.66 ug/L	5 ug/L	22/22 all locations
		selenium	AWQC chronic	5.0 ug/L	25 ug/L	2/5 PPC, 12/12 ULM
		cadmium	AWQC chronic	0.17-0.37 ug/L[1]	5 ug/L	2/5 PPC, 1/2 CFR, 6/12 ULM
		lead	AWQC chronic	1.3-3.3 ug/L[2]	10 ug/L	4/5 PPC, 6/12 ULM
		copper	AWQC acute	7.9 ug/L[3]	25 ug/L	1/5 PPC upstream only
		copper	AWQC chronic	5.5 ug/L[3]	25 ug/L	1/5 PPC upstream only
Benthic Invertebrates	Direct Contact with Bulk Sediment	antimony	TEC	2.0 mg/kg	15-24 mg/kg	2/2 CFR, 1/5 PPC
		silver	TEC	1.0 mg/kg	4 mg/kg	2/2 CFR
Benthic Invertebrates	Direct Contact with Sediment Porewater	beryllium	GLWQI Tier II SCV	0.66 ug/L	5 ug/L	14/14 all locations
		selenium	AWQC chronic	5.0 ug/L	25 ug/L	2/5 PPC, 6/6 ULM, 1/2 CFR
		cadmium	AWQC chronic	0.33-0.44 ug/L[4]	5 ug/L	2/2 CFR, 5/6 ULM
		lead	AWQC chronic	1.2-3.0 ug/L[5]	10 ug/L	4/5 PPC
Wildlife (Birds & Mammals)	Ingestion of Aquatic Invertebrates	selenium	NOAEL TRV, bird	0.23 mg/kg/day	0.52-1.4 mg/kg/day[6]	2/2 ULM, 1/1 CFR
Wildlife (Birds & Mammals)	Ingestion of Fish	selenium	NOAEL TRV, bird	0.23 mg/kg/day	1.24 mg/kg/day[6]	1/1 ULM, 1/1 CFR
		selenium	NOAEL TRV, mammal	0.05 mg/kg/day	0.4 mg/kg/day[6]	

[1] Benchmark is hardness-dependant, values shown based on hardness range of 57 to 180 mg/L
[2] Benchmark is hardness-dependant, values shown based on hardness range of 57 to 127 mg/L
[3] Benchmark is hardness-dependant, value shown based on hardness of 57 mg/L
[4] Benchmark is hardness-dependant, values shown based on hardness range of 154 to 232 mg/L
[5] Benchmark is hardness-dependant, values shown based on hardness range of 51 to 118 mg/L
[6] Dose calculated based on a tissue DL of 5 mg/kg ww.

PANEL B: Chemicals without Toxicity Benchmarks

Receptor	Exposure Pathway	Analyte
Aquatic Community (Fish & Benthic Invertebrates)	Direct Contact with Surface Water	iron, acute potassium, acute sodium, acute silver, chronic
Benthic Invertebrates	Direct Contact with Bulk Sediment	barium, potassium beryllium, selenium calcium, sodium cobalt, thallium magnesium, vanadium
Benthic Invertebrates	Direct Contact with Sediment Porewater	iron, acute potassium, acute sodium, acute silver, chronic
Wildlife (Birds & Mammals)	Ingestion of Surface Water, Sediment, and Aquatic Food Items	silver, mammals and birds antimony, birds beryllium, birds thallium, birds

Table 7-2
Summary of Uncertainties in the Supplemental Ecological Risk Assessment

Assessment Component	Uncertainty Description	Likely Direction of Error	Likely Magnitude of Error
Nature and Extent of Contamination	Samples collected may not be fully representative of variability in space or time, especially if the number of samples is small.	Unknown	Probably small
	Analytical results may be imprecise.	Unknown	Probably small
Exposure Assessment	Some exposure pathways were not evaluated.	Underestimate of risk	Unknown, could be significant
	Some chemicals could not be adequately evaluated because chemical was never detected, but detection limit was too high to detect the chemical if it were present at a level of concern.	Underestimate of risk	Usually small
	Exposure point concentrations are based on a limited measured dataset.	Use of max detect is likely to overestimate risk	Variable (depends on number of data points and magnitude of variability); can be evaluated by comparing best estimate to upper bound estimate
	Exposure parameters for wildlife receptors are based on studies at other sites.	Unknown	Probably small
	Absorption from site media is assumed to be the same as in laboratory studies.	Overestimate of risks	Possibly significant
Toxicity Assessment	Wildlife receptors selected as representative species may not capture the full range of sensitivities in site receptors.	Unknown	Probably small
	Aquatic toxicity benchmarks are based on a wide range of species, some of which do not occur at this site.	Likely to overestimate risk	Probably small
	Many chemicals lack reliable toxicity benchmarks for some receptors for some media; these chemicals are not evaluated.	Underestimation of risk	Probably small in most cases
	Available toxicity benchmarks are often based on limited data, and values must be extrapolated across species.	Unknown	Unknown, could be significant

Table 7-2 (continued)
Summary of Uncertainties in the Supplemental Ecological Risk Assessment

Assessment Component	Uncertainty Description	Likely Direction of Error	Likely Magnitude of Error
Toxicity Assessment (cont.)	Available toxicity benchmarks are often based on limited data, and values are often adjusted with uncertainty factors to account for extrapolation across dose (LOAEL to NOAEL) or duration (acute to chronic).	Likely to overestimate in most cases	Unknown, could be significant
	Dose-response curves and toxicity benchmarks based on laboratory studies are assumed to be applicable to free-living populations in the field.	Unknown; variability maybe higher in wild populations than laboratory animals, hence high end risks may tend to be underestimated	Unknown, probably minor
Risk Characterization	Interactions between chemicals are difficult to account for; effects of one chemical may increase, decrease, or have no effect on other chemicals.	Unknown	Unknown, but probably small
	Estimation of population-level effects from HQ calculations is difficult and subject to professional judgement.	Unknown	Unknown, probably small in most cases

APPENDIX A

Detailed Analytical Results for Samples Utilized in this Assessment

Table 1a - Surface Water, Dissolved Fraction
Table 1b - Surface Water, Total Fraction
Table 2 - Bulk Sediment
Table 3 - Sediment Porewater, Dissolved Fraction
Table 4 - Aquatic Food Items
Table 5 - Aquatic Food Items (from USFWS, 1997)

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APPENDIX A, Table 1a

Measured Dissolved Surface Water Concentrations in Samples Collected During the 2003 Field Investigation

	Canyon Ferry Reservoir (Ref)		Lower Lake			Prickly Pear Creek (upstream >>> downstream)				
Station ID	CFR 1	CFR 2	LL 1	LL 2	LL 3	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
ALUMINUM	200 U	102	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
ANTIMONY	60 U	8.3	393	417	428	60 U	60 U	60 U	60 U	60 U
ARSENIC	12.3	16.4	200	216	214	15 U	15 U	11.4	12.4	15 U
BARIUM	80.6	89.9	40	41.5	42.8	200 U	27.1	28.9	26.9	49.6
BERYLLIUM	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
CADMIUM	1 U	1 U	6.9	6.6	6.8	1 U	0.1	0.23	0.17	1 U
CALCIUM	34500	41400	63900	67600	69800	17200	32500	34000	33800	41000
CHROMIUM	1.2	1.1	0.84	10 U	10 U	10 U	10 U	0.85	10 U	10 U
COBALT	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
COPPER	25 U	3.6	20.2	20.7	21.3	25 U	25 U	3.4	25 U	25 U
IRON	88	100 U	122	114	172	70.7	81.2	177	123	58.8
LEAD	10 U	10 U	17.5	23.6	22.7	10 U	10 U	10 U	10 U	10 U
MAGNESIUM	14100	18500	7470	7630	8000	3310	8050	8030	8280	9470
MANGANESE	15 U	15 U	199	204	207	14.6	34.8	73.4	37.6	13.3
NICKEL	40 U	40 U	2.8	3.7	4.4	40 U	40 U	40 U	40 U	40 U
POTASSIUM	4890	5610	21600	21800	22700	1510	2730	3340	3410	3460
SELENIUM	13.7	15.8	52.3	50.5	49.3	35 U	35 U	9.3	8.4	7.1
SILVER	1.5	R	1.4	10 U	0.72	R	R	0.69	0.69	1.3
SODIUM	27300	31900	393000	396000	405000	5400	17900	19600	19400	15800
THALLIUM	25 U	25 U	72.9	71	71.4	25 U	25 U	25 U	25 U	25 U
VANADIUM	7.4	9.6	50 U	50 U	50 U	2	2.9	3.6	2.9	3.9
ZINC	63.6	64.6	70.1	84.8	103	176	137	130	71.3	113
Hardness (mg/L)	*144*	*180*	*190*	*200*	*207*	*56.6*	*114*	*118*	*118*	*141*

	Upper Lake/Marsh Area											
Station ID	ULM 1	ULM 2	ULM 3	ULM 4	ULM 5	ULM 6	ULM 7	ULM 8	ULM 9	ULM 10	ULM 11	ULM 12
ALUMINUM	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
ANTIMONY	60 U	10.3	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U
ARSENIC	7.5	15 U	15 U	15 U	6.9	8.2	15 U	15 U	15 U	15 U	15 U	15 U
BARIUM	13.2	43.5	34.6	32	33	25.1	30	36.8	28.8	35.8	33	39.1
BERYLLIUM	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
CADMIUM	1 U	0.43	0.12	1 U	1 U	1 U	0.13	0.37	0.29	0.25	1 U	1 U
CALCIUM	34000	36600	34500	33800	33800	33500	34300	47000	33000	35100	33800	33700
CHROMIUM	0.77	2.1	10 U	10 U	10 U	10 U	10 U	1	10 U	10 U	10 U	10 U
COBALT	50 U	2	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
COPPER	3.2	11.7	3.2	3.4	3.5	3.7	3.3	7.7	5.1	4.1	3.1	4.8
IRON	103	112	185	119	114	89.7	106	154	106	75.2	164	59.5
LEAD	10 U	10 U	3.9	3.6	10 U	10 U	10 U	10 U	10 U	6.1	10 U	6.6
MAGNESIUM	13200	8760	8080	7790	7920	8130	7810	11000	8270	8220	8020	8420
MANGANESE	25.1	1940	66.1	83.2	164	15.3	51.6	899	35.1	71.1	39.3	66.1
NICKEL	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U
POTASSIUM	3690	2480	2910	2870	2890	2970	2940	515	971	3070	2730	2970
SELENIUM	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U
SILVER	1.1	10 U	0.77	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
SODIUM	23300	17600	19100	19000	19400	19200	19500	22400	20500	19600	18600	19000
THALLIUM	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
VANADIUM	2.1	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
ZINC	60 U	123	30.8	45.6	139	45.9	37.6	119	73.1	57.3	56.4	60 U
Hardness (mg/L)	*139*	*127*	*119*	*116*	*117*	*117*	*118*	*163*	*116*	*121*	*117*	*119*

Units are ug/L, unless noted otherwise.

U = Not detected, detection limit shown

R = Analytical result was rejected by validator

APPENDIX A, Table 1b
Measured Total Surface Water Concentrations in Samples Collected During the 2003 Field Investigation

	Canyon Ferry Reservoir (Ref)		Lower Lake			Prickly Pear Creek (upstream >>> downstream)				
Station ID	CFR 1	CFR 2	LL 1	LL 2	LL 3	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
ALUMINUM	6880	5770	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
ANTIMONY	6.9	60 U	375	423	437	10.9	60 U	60 U	60 U	60 U
ARSENIC	14.8	11.5	221	239	242	15 U	15 U	11.5	10.1	15 U
BARIUM	125	119	38.3	43.4	43.9	200 U	29.3	27.6	27.9	49.5
BERYLLIUM	0.52	0.43	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
CADMIUM	0.17	0.52	8.2	8.3	8.9	1 U	0.21	0.36	0.29	0.11
CALCIUM	44800	44800	60000	68300	69600	17600	34000	31100	33200	40600
CHROMIUM	6.5	5.7	1	0.67	0.9	10 U	10 U	10 U	10 U	10 U
COBALT	2.2	2.1	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
COPPER	7.5	10.8	26.8	30.1	31.8	4.5	5	4.7	4.4	4.3
IRON	5760	5370	356	400	442	191	269	368	327	90
LEAD	3.9	14.9	65.9	78.9	87.1	10 U	4.1	4.7	4.9	10 U
MAGNESIUM	19900	19600	7260	7800	7990	3440	8160	7400	7690	9240
MANGANESE	63.5	61.1	204	221	224	20.3	56.2	89	67.5	15.9
NICKEL	4.9	5.7	40 U	3.9	4.3	40 U	40 U	40 U	40 U	40 U
POTASSIUM	7010	6800	20400	22600	23000	1560	2870	3100	3360	3450
SELENIUM	9.6	13.7	48.1	50.4	54.1	35 U	35 U	35 U	35 U	35 U
SILVER	R	0.81	2.[illegible]	1.2	10 U	10 U	10 U	10 U	10 U	10 U
SODIUM	30800	32400	359000	422000	426000	5180	18900	17800	19100	15500
THALLIUM	25 U	25 U	65.7	66	67.5	25 U	25 U	25 U	25 U	25 U
VANADIUM	15.5	14.1	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
ZINC	103	118	77.5	125	123	80.9	65.3	86.9	68.2	94.7
Hardness (mg/L)	*194*	*193*	*180*	*203*	*207*	*58.1*	*119*	*108*	*115*	*139*

	Upper Lake/Marsh Area											
Station ID	ULM 1	ULM 2	ULM 3	ULM 4	ULM 5	ULM 6	ULM 7	ULM 8	ULM 9	ULM 10	ULM 11	ULM 12
ALUMINUM	132	828	200 U	200 U	1620	168	200 U	200 U	200 U	200 U	200 U	294
ANTIMONY	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U
ARSENIC	15 U	21.4	15 U	9.1	14.4	10.3	15 U	31.5	15 U	7.7	15 U	8.4
BARIUM	14.6	63.5	32.2	32	45.9	27.2	26.8	58.9	35.4	34.2	35	45.5
BERYLLIUM	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
CADMIUM	0.21	2.1	0.44	0.11	2.9	0.25	0.18	3.1	1.4	0.85	1.1	5.6
CALCIUM	32600	36500	30400	32500	34000	32300	30200	44500	31300	31600	31700	31000
CHROMIUM	10 U	2.9	0.67	10 U	1.9	4.1	0.96	2.4	1.1	10 U	0.69	0.89
COBALT	50 U	2.7	50 U	50 U	1.1	50 U	50 U	50 U	50 U	50 U	50 U	50 U
COPPER	4	23.4	4.1	4	27.7	7.9	3.8	21.5	13.4	5.4	8.3	22.1
IRON	120	4560	265	293	2040	215	230	8370	1000	283	201	603
LEAD	6.9	57.6	16.5	10 U	115	19.9	10 U	68.4	20.6	31.6	28.2	156
MAGNESIUM	12500	8750	7480	7930	8890	8340	7650	11100	8060	7830	7910	7850
MANGANESE	47.6	2180	70.8	85.2	241	40.7	49.5	1740	382	90.1	79.2	97.9
NICKEL	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U
POTASSIUM	3610	2740	2720	2910	3490	3000	2670	687	1160	2840	2780	2870
SELENIUM	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U
SILVER	10 U	10 U	0.86	10 U	R	0.81	10 U	0.8	10 U	10 U	R	0.94
SODIUM	22200	17200	16700	17800	18800	18100	16600	20000	18600	17600	17700	17600
THALLIUM	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
VANADIUM	2.7	5.6	50 U	50 U	3.9	50 U	50 U	3.2	50 U	50 U	50 U	50 U
ZINC	27.4	253	60 U	60 U	140	60 U	60 U	127	59.3	60 U	31.9	97.9
Hardness (mg/L)	*133*	*127*	*107*	*114*	*122*	*115*	*107*	*157*	*111*	*111*	*112*	*110*

Units are ug/L, unless noted otherwise.
U = Not detected, detection limit shown
R = Analytical result was rejected by validator

APPENDIX A, Table 2
Measured Bulk Sediment Concentrations in Samples Collected During the 2003 Field Investigation

	Canyon Ferry Reservoir (Ref)		Lower Lake			Prickly Pear Creek				
						(Ref)	(upstream >>> downstream)			
Analyte	CFR 1	CFR 2	LL 1	LL 2	LL 3	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
ALUMINUM	13200	17600	4440	13000	11500	8590	7750	9500	10100	4880
ANTIMONY	23.2 U	24.2 U	990	353	530	R	15.5 U	4.1	4.5	1.9
ARSENIC	12.4	15.6	1660	2730	3030	11.5	52.1	122	250	32.1
BARIUM	166	175	173	245	205	106	135	250	352	85.3
BERYLLIUM	1.5	1.8	0.56	1.8	1.3	0.91	1.1	1.3	1.4	0.63
CADMIUM	0.97	1.2	1230	1150	2680	3.5	6	22.8	36.8	4.1
CALCIUM	30100	39800	4350	13700	17700	4830	7510	8300	8730	3740
CHROMIUM	21.2	23.6	10.4	22.1	21.9	18	10.3	15.9	21.2	8.2
COBALT	8.4	9.3	25.6	35.1	34.6	9.9	12.3	15.5	21.2	7
COPPER	28.1	33.6	1920	1900	2600	59.7	93.9	221	480	44.1
IRON	16100	19500	17500	35200	30300	20700	18600	24800	38100	11800
LEAD	17.2	23.5	9470	9420	14400	104	370	878	1090	203
MAGNESIUM	10100	14100	2860	8990	6950	4590	7130	6880	6430	3890
MANGANESE	198	258	851	1230	1370	720	672	3920	9030	558
MERCURY	0.22 U	0.29 U	53.3	38	48.4	R	0.43	2.5	3.1	0.27
NICKEL	16.8	18.8	24.7	36.4	34	10.4	9.9	12.7	16.1	6.2
POTASSIUM	2920	3780	1670	5900	4510	2700	3890	4060	3830	2070
SELENIUM	13.5 U	14.1 U	432	221	316	R	1.3	2.8	5.3	1.1
SILVER	3.9 U	4 U	101	93.7	141	R	2.6 U	0.85	2.5	2.4 U
SODIUM	335	370	1130	2340	1860	173	159	282	481	145
THALLIUM	9.7 U	10.1 U	1980	700	884	R	6.5 U	R	R	6 U
VANADIUM	24.1	27.8	20.4	57.7	44.4	39.7	34	44.1	55.2	24.8
ZINC	81.4	102	4490	6080	6930	454	925	1860	3930	444

	Upper Lake/Marsh Area											
Analyte	ULM 1	ULM 2	ULM 3	ULM 4	ULM 5	ULM 6	ULM 7	ULM 8	ULM 9	ULM 10	ULM 11	ULM 12
ALUMINUM	15700	14500	15700	11900	9490	20000	9650	12200	15600	14200	17500	15900
ANTIMONY	19.5	1.7	5.6	16.8	10.9	68.6	1.2	6.5	0.43	60	112	64.9
ARSENIC	229	121	162	116	124	326	54.6	297	146	337	581	452
BARIUM	150	213	282	143	111	228	120	149	214	179	201	228
BERYLLIUM	1.5	1.9	2.1	1.2	1	1.9	1	1.3	1.7	1.6	2	2
CADMIUM	112	12.2	66.9	42.5	46.6	199	15	38.3	17.7	238	338	316
CALCIUM	8710	8740	10500	5400	3830	9980	4580	5070	7090	8000	9150	9140
CHROMIUM	19.5	20.5	22.3	15.6	13.1	26.7	12.4	15.8	20.9	20.1	27.3	24.7
COBALT	12.2	17.5	19.2	11.5	9.1	18.8	8.6	13.6	17.4	18	24.1	21.5
COPPER	686	191	430	404	332	1270	158	391	180	1310	2290	1970
IRON	23500	32600	29200	18400	16000	34400	16300	19300	26200	25600	30200	29300
LEAD	4270	594	1470	1170	1610	5360	486	1850	529	5140	10400	8990
MAGNESIUM	7080	8470	9320	5540	4520	8450	4780	5730	9820	7430	9420	8600
MANGANESE	720	2520	955	576	484	747	472	890	755	911	1300	1190
MERCURY	14.2	0.59	4.7	5.9	14.5	27.3	1.2	10.1	2.1	28.3	50.6	59.1
NICKEL	17.9	16.2	20.1	12.1	10.1	22.5	9.3	13.4	17.9	19.6	24.8	23
POTASSIUM	4160	4950	5320	3380	2770	5460	2870	3100	5480	4320	5140	4990
SELENIUM	14	2.8	4.3	4.5	3.8	14	3.2	5.2	2.9	11.5	19.9	20.4
SILVER	29.1	0.65	10.2	14	11.9	59.3	2.7	14.2	2.6 U	64.1	127	107
SODIUM	359	341	398	219	163	493	177	193	219	321	315	353
THALLIUM	1.9	R	R	10.5 U	8.3 U	4.8	8.5 U	6.6 U	6.4 U	R	R	R
VANADIUM	41.9	56.2	50.4	34	34.3	58.9	27.1	46.2	57.5	43.6	59.4	52.4
ZINC	1810	1680	3540	2100	1680	4200	1360	2120	1670	4260	6550	6420

Units are mg/kg.
U = Not detected, detection limit shown
R = Analytical result was rejected by validator

APPENDIX A, Table 3

Measured Dissolved Sediment Porewater Concentrations in Samples Collected During the 2003 Field Investigation

	Canyon Ferry Reservoir (Ref)		Lower Lake	Upper Lake/Marsh Area						Prickly Pear Creek				
										(Ref)	(upstream >>> downstream)			
Analyte	CFR 1	CFR 2	LL 1	ULM 3	ULM 4	ULM 6	ULM 7	ULM 10	ULM 12	PPC 1	PPC 2	PPC 3	PPC 4	PPC 5
ALUMINUM	200 U	200 U	145	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U	200 U
ANTIMONY	60 U	60 U	483	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	60 U	12.1	60 U
ARSENIC	31.5	13.6	2530	15 U	15 U	15 U	15 U	15 U	15 U	15 U	15 U	8	10.3	15 U
BARIUM	107	110	42.9	142	113	180	112	126	183	200 U	200 U	27.2	30.3	108
BERYLLIUM	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
CADMIUM	5 U	5 U	3.2	5 U	5 U	5 U	0.35	5 U	5 U	0.38	1	0.27	0.31	2.2
CALCIUM	54600	55700	66300	52800	45600	68300	85300	58100	65900	16000	34900	33300	34100	61300
CHROMIUM	0.99	1.5	4.6	1.6	2	2.3	2.7	3.1	2.7	1	0.75	10 U	10 U	1.2
COBALT	50 U	50 U	50 U	50 U	50 U	50 U	1.2	50 U	50 U	50 U	50 U	50 U	50 U	3.8
COPPER	3.2	4	7.6	3.5	25 U	3.8	25 U	3.3	3.1	3.2	4.3	6.4	6	3.9
IRON	83.8	100 U	323	825	2200	260	19900	2390	5080	47.6	89.4	82.6	82.2	55.2
LEAD	10 U	10 U	17.7	10 U	10 U	4.7	10 U	7.5	10.5	10 U	10 U	10 U	10 U	10 U
MAGNESIUM	22000	22500	6660	12200	9760	14200	18600	12400	13900	2770	7480	8020	8050	14200
MANGANESE	237	358	773	916	1990	1840	2700	3010	2460	939	547	15 U	15 U	1260
MERCURY	--	--	--	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	40 U	40 U	6.1	3.1	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U	40 U
POTASSIUM	4590	4920	22800	3580	3860	5780	4580	4520	5070	1460	2740	3320	3260	3000
SELENIUM	35 U	6.9	7.2	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	8.1	10.5	14.1
SILVER	0.85	0.95	1.5	0.94	10 U	1.1	1.2	1.4	0.78	R	1.2	0.7	0.99	1
SODIUM	31900	30200	399000	19900	18900	20700	20400	19400	19200	3950	16200	18800	18700	16000
THALLIUM	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
VANADIUM	50 U	50 U	4.6	50 U	50 U	50 U	50 U	50 U	50 U	2.6	2.9	2.9	3.8	5.4
ZINC	60 U	60 U	40.9	60 U	60 U	60 U	60 U	30	60 U	95.7	194	187	140	170
Hardness (mg/L)	*227*	*232*	*193*	*182*	*154*	*229*	*290*	*196*	*222*	*51.4*	*118*	*116*	*118*	*212*

Units are ug/L, unless noted otherwise.
U = Not detected, detection limit shown
R = Analytical result was rejected by validator
-- = Not Analyzed

APPENDIX A, Table 4
Trace Element Concentrations in Aquatic Tissues from the Upper Lake/Marsh Area and Canyon Ferry Reservoir

Media: Aquatic Plants/Algae (mg/kg ww)

Analyte	Canyon Ferry (Ref)	Upper Lake/Marsh Area							
	CFR 1	ULM 1	ULM 11	ULM 2	ULM 5	ULM 8	ULM 9	UL comp.	UL comp.
Arsenic	2 U	2 U	4	11	4	15	17	11	3
Cadmium	0.6	0.4	1.2	0.9	1.4	2.6	4.2	1.5	1.8
Copper	5.8	1.7	8.4	6.3	14.3	7.4	18.8	10.4	4.9
Lead	11.4	3	37.8	10.4	50	13.4	41.8	21.2	29.4
Selenium	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Zinc	18	8	35	51	73	63	94	45	46

Media: Aquatic Invertebrates (mg/kg ww)

Analyte	Canyon Ferry (Ref)	Upper Lake/ Marsh Area	
	CFR 2	ULM 1	ULM 10
Arsenic	2 U	2 U	2 U
Cadmium	0.2	0.8	9.6
Copper	10	31.3	79.5
Lead	4.1	11.9	105.1
Selenium	5 U	5 U	5 U
Zinc	17	28	67

Media: Rainbow Trout Stomach Contents (mg/kg ww)

Analyte	Upper Lake/ Marsh Area		
	ULM 11	ULM 3	UL
Arsenic	2 U	2 U	3
Cadmium	0.4	0.4	9.6
Copper	9.2	7.2	18.5
Lead	3.1	3.4	159.8
Selenium	5 U	5 U	5 U
Zinc	64	51	188

Media: Fish (mg/kg ww)

Analyte	Canyon Ferry (Ref)	Upper Lake/ Marsh Area						
	Forage	Forage	RBT Kidney	RBT Liver	RBT Fillet	RBT Fillet	RBT Fillet	RBT Wh. Body
Arsenic	2 U	2 U	2 U	2 U	2 U	2 U	--	--
Cadmium	0.2 U	1.4	0.2 U	0.9	0.2	0.2 U	--	--
Copper	2.1	9.1	2.1	140.1	1.6	1.3	--	--
Lead	0.8 U	25	0.8 U	1.3	0.8 U	0.8 U	--	--
Mercury	0.025	0.065	--	--	--	--	0.217	0.106
Selenium	5 U	5 U	5 U	12	5 U	5 U	--	--
Zinc	35	66	35	51	13	5	--	--

RBT = rainbow trout

APPENDIX A, Table 5

Trace Element Concentrations (ug/g ww) in Benthic Invertebrates and Fish from Prickly Pear Creek Above and Below the East Helena Site

Metal	**Invertebrate Composite**				**Stonefly Larvae**			
	Upstream (N = 4)		Downstream (N = 6)		Upstream (N = 3)		Downstream (N = 4)	
	geomean	min - max	geomean	min - max	geomean	min - max	geomean	min - max
Arsenic	3.18	1.56 - 4.34	3.84	2.1 - 6.06	1.48	0.518 - 2.66	3.38	2.2 - 5.26
Cadmium	0.548	0.41 - 0.646	1.262	0.316 - 4.08	0.516	0.246 - 1.722	0.96	0.644 - 1.484
Copper	15.98	8.34 - 26.6	26.02	18.64 - 39.2	8.96	8.58 - 9.38	14.48	11.04 - 19.88
Lead	7.02	3.5 - 16.7	9.54	3.56 - 16.48	4.96	5.22 - 9.08	13.7	7.72 - 22.2
Zinc	67.2	39.4 - 92.8	49.4	19.4 - 87.2	71.2	62 - 83.6	96	67.6 - 132.2

Source: USFWS (1997) - Table 3

Converted from dry weight to wet wight assuming 20% solids.

[shaded] significantly higher than upstream (Mann-Whitney U-test, $p < 0.05$)

Metal	**Rainbow Trout**				**Brook Trout**			
	Upstream (N = 4)		Downstream (N = 5)		Upstream (N = 3)		Downstream (N = 3)	
	geomean	min - max	geomean	min - max	geomean	min - max	geomean	min - max
Arsenic	0.405	0.27 - 0.763	0.408	0.143 - 0.968	0.245	0.148 - 0.315	NC	<0.125 - 0.258
Cadmium	0.118	0.07 - 0.32	0.263	0.080 - 1.135	0.08	0.045 - 0.112	0.095	0.068 - 0.149
Copper	4.28	2.50 - 7.475	2.48	1.25 - 3.98	3.80	2.36 - 5.43	4.3	3.45 - 6.68
Lead	0.72	0.18 - 3.275	0.755	0.132 - 6.4	0.275	<0.126 - 0.605	0.115	<0.126 - 0.181
Zinc	35.0	28.5 - 47.25	37.8	25.8 - 56.3	49.5	45.0 - 55.5	39.0	26.3 - 54.3

Source: USFWS (1997) - Table 4

NC = Not Calculated

Converted from dry weight to wet wight assuming 25% solids.

Metal	**Brown Trout**				**Rainbow Trout**				**White Sucker**	
	Upstream (N = 3)		Downstream (N = 3)		Upstream (N = 3)		Downstream (N = 3)		Upstream	Downstrea
	geomean	min - max	geomean	min - max	geomean	min - max	geomean	min - max	(N = 1)	m (N = 1)
Mercury	0.038	0.025 - 0.054	NC	<0.0251 - <0.0255	NC	<0.0253 - 0.032	NC	<0.0251 - <0.0253	0.0478	<0.0254

Source: USFWS (1997) - Addendum

NC = Not Calculated

Converted from dry weight to wet wight assuming 25% solids.

USFWS (1997) - Biological Indices of Lead Exposure in Relation to Heavy Metal Residues in Sediment and Biota from Prickly Pear Creek and Lake Helena, Montana. USFWS, Region 6. Contaminant Report # R6/214H/97. [Mercury data provided in faxed addendum]

APPENDIX B
SELECTION OF TOXICITY BENCHMARKS AND WILDLIFE TOXICITY REFERENCE VALUES

Overview

The hazard quotient approach to risk characterization is based on comparison of site-related indices of exposure to appropriate benchmarks of toxicity. These benchmarks may be concentration-based (e.g., the concentration in soil, sediment, surface water, or diet), or may be dose-based. Each benchmark is contaminant-specific, receptor-specific and is usually medium-specific.

For this assessment, all toxicity benchmarks are based on values developed by various regulatory agencies and published in the literature. This appendix describes the various sources of benchmark values reviewed for this risk assessment, and identifies the hierarchy used to prioritize values when more than one value was available.

This appendix is organized into the following sections:

Aquatic Receptors (Fish & Benthic Macroinvertebrates)

B-1 Benchmarks for Direct Contact With Surface Water
B-2 Benchmarks for Direct Contact with Sediment

Wildlife Receptors (Birds & Mammals)

B-3 Dose-Based Toxicity Reference Values

Aquatic Receptors (Fish & Benthic Macroinvertebrates)

B-1 Benchmarks for Direct Contact With Surface Water

Toxicity values for the protection aquatic life from contaminants in surface water are available from several sources. Each of these sources is described briefly below.

National Ambient Water Quality Criteria

The USEPA has established acute and chronic National Ambient Water Quality Criteria (NAWQC) values for surface waters for the protection of aquatic communities (USEPA 2002a). The acute NAWQC is intended to protect against short-term (48 to 96 hour) lethality, while the chronic NAWQC is intended to protect against long-term effects on growth, reproduction, and survival. The NAWQC values are not species-specific, but are designed to protect 95% of the aquatic species for which toxicity data are available (USEPA 1985).

Great Lake Water Quality Initiative Tier II Values

The approach used for the derivation of Great Lake Water Quality Initiative (GLWQI) Tier II secondary acute values (SAVs) and secondary chronic values (SCVs) is similar to that used to derive NAWQC. Data and detailed methods and are described in Appendix B of Suter and Tsao (1996). In brief, a secondary acute value is derived by taking the lowest genus mean acute value (GMAV) and dividing it by the Final Acute Value Factor (FAVF). The FAVF is based on the number of studies and types of species used to derive the FAV. Once an SAV is calculated, the geometric mean of each of the secondary acute-chronic ratios (SACR) is found. The SCV is calculated by dividing the SAV by the SACR.

USEPA Region 4 Screening Values

Screening level freshwater benchmarks for are also available from USEPA Region 4 (USEPA, 2002b). The Region 4 acute and chronic screening values are equal to the lowest effect level (LEL) divided by 10 to protect for sensitive species. If no chronic LEL is available, the chronic screening value is equal to the lowest acute LC50 or EC50 divided by 10.

Canadian Water Quality Guidelines

The Canadian Council of Ministers of the Environment (CCME) have established water quality guidelines (WQG) for the protection of aquatic life in Canadian waters (CCME, 1991, 2001). The protocol for deriving water quality guidelines is similar to the NAWQC procedure. Protocol details are available on the CCME WQG website. In brief, the guideline is equal to the most sensitive LOEL from a chronic exposure study divided by a safety factor of 10. If a chronic LOEL is not available, the WQG is equal to the acute LC50 divided by the acute/chronic ratio (ACR). The CCME WQG is designed to be protective of "100% of the aquatic life species, 100% of the time".

Oak Ridge National Laboratory Lowest Chronic Values and EC20 Values

Oak Ridge National Laboratory (ORNL) has compiled summary tables of the lowest chronic values (LCVs) in surface water for fish, daphnids, non-daphnid invertebrates, aquatic plants, and aquatic populations (Suter and Tsao, 1996). In some instances, the LCVs were extrapolated from LC50 and EC50 data using fish and daphnid-specific equations. ORNL also summarized EC20 data for fish, daphnids, sensitive species, and aquatic populations. The EC20s are based on a level of biological effect and are intended to be indices of population production (Suter and Tsao, 1996).

USEPA Region 5 Ecological Screening Levels

The USEPA Region 5 has derived ecological screening levels (ESLs) for RCRA Appendix IX Hazardous Constituents in soil, surface water, sediment, and air (USEPA 1999). The surface water ESL is based on either an aquatic benchmark, which is protective of direct contact exposures, or a wildlife receptor-specific benchmark, which is protective of ingestion exposures in the mink and belted kingfisher. The surface water ESL does not distinguish whether it is derived based on aquatic or wildlife exposure.

OSWER Ecotox Thresholds

The OSWER Ecotox Thresholds (ETs) were presented in a USEPA ECO Update Bulletin (USEPA, 1996). The bulletin provided an overview of the development and use of ecological benchmarks for surface water and sediment. For surface water, the ET is based on either the chronic NAWQC or the GLWQI Tier II value.

Because the USEPA Region 5 ESLs do not make a distinction between surface water benchmarks derived from aquatic data and wildlife data, these values are excluded from consideration as a benchmark source. The OSWER ETs were also excluded because they are based on primary sources (NAWQC, GLWQI Tier II) that had been previously reviewed. For the remaining sources, selection of the surface water toxicity benchmarks for aquatic receptors was based on the following hierarchy:

- National Ambient Water Quality Criteria
- Great Lake Water Quality Initiative Tier II Values
- USEPA Region 4 Screening Values
- Canadian Water Quality Guidelines
- Oak Ridge National Laboratory LCVs and EC20s

The surface water benchmark values from these sources are shown in Table B-1a, along with the values selected for use in the risk assessment. For many metals and metalloids, the NAWQC values are dependent on the hardness of the water, so the precise value of the acute and chronic NAWQC that applies to a sample depends on the hardness of that sample. The equations and parameters used to calculate the acute and chronic NAWQC values for these metals are presented in Table B-1b.

References:

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B-2 Benchmarks for Direct Contact with Sediment

Toxicity values for the protection benthic macroinvertebrates from contaminants in freshwater sediment are available from several sources. Each of these sources is described briefly below.

Consensus-Based Sediment Quality Guidelines

MacDonald et al. (2000) issued consensus-based sediment quality guidelines (SQGs) for 28 chemicals of concern, in an effort to focus on agreement among the various sediment quality guidelines. For each chemical of concern, a threshold effect concentration (TEC) and a probable effect concentration (PEC) were identified based on available sediment toxicity literature. The consensus-based TECs were calculated by determining the geometric mean of all threshold effect values from the literature. The consensus-based PECs were calculated by determining the geometric mean of all probable effect values from the literature. A summary of the types of sediment effect concentrations included in the TEC and PEC calculations is provided in MacDonald et al. (2000).

The predictive reliability of these values were also evaluated. The predictive ability analyses were focused on the ability of each SQG when applied alone to classify samples as either toxic or non-toxic. Sediment toxicity should be observed only rarely below the TEC and should be frequently observed above the PEC. Individual TECs were considered reliable if more than 75% of the sediment samples were correctly predicted to be non-toxic. Similarly, the individual PEC was considered reliable if greater than 75% of the sediment samples were correctly predicted to be toxic. The SQGs were considered to be reliable only if a minimum of 20 samples were included in the predictive ability evaluation (MacDonald et al. 2000).

Because field collected sediments contain a mixture of chemicals, a second analysis was completed to investigate whether the toxicity of a sediment could be predicted based on the average of the PEC ratios for the sediment, using only the PEC values that were found to be reliable. It was found that 92% of sediment samples with a mean PEC quotient > 1.0 were toxic to one or more species of aquatic organisms. The mean PEC quotient was found to be highly correlated with incidence of toxicity ($R^2 = 0.98$) (MacDonald et al. 2000).

ARCS Sediment Effect Concentrations

As part of the Assessment and Remediation of Contaminated Sediment (ARCS) Project, Ingersoll et al. (1996) compiled freshwater sediment toxicity data from nine different sites in the United States and identified a series of sediment effect concentrations (SECs) for a series of metals in sediment. The SECs are defined as the concentrations of individual contaminants in sediment below which toxicity is rarely observed and above which toxicity is frequently observed. The database was compiled to classify toxicity data for Great Lakes sediment samples and is segregated into "effect" data and "no effect" data. Ingersoll et al.(1996) derived five different SECs; effect range low (ERL), effect range median (ERM), threshold effect level (TEL), probable effect level (PEL) and no effect concentration (NEC). The derivation of each of these SECs is presented below:

- effect range low (ERL) = 10th percentile of adverse effect data
- effect range median (ERM) = 50th percentile (median) of adverse effect data
- no effect range median (NERM) = 50th percentile (median) of no effect data
- no effect range high (NERH) = 85th percentile of no effect data
- threshold effect level (TEL) = geometric mean of ERL and NERM
- probable effect level (PEL) = geometric mean of ERM and NERH
- no effect concentration (NEC) = maximum of no effect data

The ERL is defined as the concentration below which adverse effects are unlikely to occur. The ERM is defined as the concentration of a chemical above which effects are frequently or always observed or predicted among most species. The NEC is the maximum concentration of a chemical in sediment that does not significantly adversely affect the particular response when compared to the control.

USEPA Region 5 Ecological Screening Levels

The USEPA Region 5 Ecological Screening Levels (ESLs) for sediment were developed based on available federal freshwater sediment criteria and state-promulgated sediment quality guidelines (USEPA 1999). If no freshwater guidelines were available, marine criteria were used. For those chemicals for which no guidelines were available, an interim ESL was developed using the equilibrium partitioning approach. These interim guidelines were developed for both nonpolar and polar organic constituents. The equilibrium partitioning method is generally only applied to nonpolar organics, however, it was assumed to be a satisfactory method for organics for use on a screening level approach (USEPA 1999). The ESL was derived from the lowest federal, state or interim water quality guideline and assumes a total organic carbon content of 1%.

NOAA Sediment Effect Concentrations

The National Oceanic and Atmospheric Administration (NOAA) compiled sediment data from studies performed in both freshwater and saltwater (originally presented in NOS OMA Technical Memo 52, Long and Morgan 1990).The NOAA ERL and ERM were developed using the same procedures as outlined for the ARCS Project (Ingersoll et al. 1996). The NOAA ERL is defined as the concentration of a chemical in sediment below which adverse effects are rarely observed or predicted among sensitive species. The NOAA ERM is representative of concentrations above which effects frequently occur. The original data set used by Long and Morgan (1990) has since been supplemented with additional saltwater data, therefore these additional marine reports are not applicable (ie: Long et al. 1995).

USEPA Region 4 Screening Levels

The USEPA Region 4 Screening Levels are derived from three different sediment effects data sets including NOAA freshwater and marine data from Long and Morgan (1990), additional NOAA marine data from Long et al. (1995), and Florida State Department of Environmental Protection marine data from MacDonald et al. (1996). The sediment effect level is based on the reported ERL from each study. In instances when the USEPA Contract Laboratory Program (CLP) practical quantitation limit (PQL) is above the effect level, the screening value is equal to the CLP PQL (USEPA 2002).

CCME Sediment Quality Guidelines

The Canadian Council of Ministers of the Environment (CCME) derived sediment quality guidelines to support protection and management strategies for freshwater, estuarine, and marine ecosystems (CCME 1995). Guideline derivation protocols are detailed in CCME (1995) and are similar to the procedures described previously for the ARCS Project (Ingersoll et al. 1996). Separate guidelines were derived for freshwater and marine sediments (CCME 2001). The freshwater interim sediment quality guideline (ISQG) was equal to the TEL and is representative of the concentration below which adverse effects are not anticipated for aquatic life associated with bed sediments (CCME 1995). A PEL was also calculated to establish concentrations above which adverse effects are likely to occur.

Ontario Sediment Effect Levels

Persaud et al. (1993) derived sediment effect levels for the protection of aquatic organisms in Ontario, Canada. Three types of sediment quality guidelines were developed; a No Effect Level (no toxic effects), a Low Effect Level (tolerable by benthic species), and a Severe Effect Level (detrimental to most benthic species). A summary and review of the available approaches to sediment guideline development and the protocol for the derivation of the Ontario values is described in detail in Persaud et al. (1993). Briefly, the No Effect Level is obtained through a chemical equilibrium approach using water quality standards. Because the equilibrium partitioning approach is only predictive for nonpolar organics, a No Effect Level is not derived for metals and polar organics. The Low Effect Level and Severe Effect Level are based on the 5^{th} and 95^{th} percentiles of all effects data for bulk sediment analysis, respectively. For non-polar organics these concentrations were normalized for total organic carbon.

Of these sources, the following are excluded from use in this risk assessment due to inadequate documentation of derivation methodology, use of site-specific assumptions, use of marine or estuarine sediments, use of inappropriate receptors, or errors in benchmark derivation.

- USEPA Region 5 Screening Levels
- USEPA Region 4 Screening Levels

- CCME Sediment Quality Guidelines (ISQG/PEL)
- Ontario Sediment Effect Levels (Low/Severe)

Of the remaining sources, a benchmark selection hierarchy is established as follows and a summary of all selected sediment toxicity benchmarks is shown in Table B-2.

- Consensus based TEC (MacDonald et al., 2000)
- ARCs TEL (Ingersoll et al., 1996)
- NOAA ERL (Long and Morgan, 1990)

References:

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Wildlife Receptors (Birds & Mammals)

B-3 Dose-Based Toxicity Reference Values

Numerous studies have been conducted that provide information on toxicity associated with experimental exposures for a variety of birds and mammals. Because conducting an extensive literature search and rigorous review of all experimental studies and developing site-specific Toxicity Reference Values (TRVs) for each wildlife receptor for each chemical is not feasible, dose-based TRVs for birds and mammals were compiled from secondary sources.

Because the purpose of a wildlife risk assessment is to evaluate wildlife exposures from ingestion of contaminated media from a site over the lifetime of the receptor, TRVs derived from studies in which the exposure route was oral (eg: via ingestion in diet or water or via gavage), and dosing occurred over a long period of time (chronic exposure) or during a critical lifestage period are preferred. In addition, wildlife TRVs which represent relevant toxicity endpoints for population sustainability (eg: growth, reproduction, mortality) are preferred over endpoints such as tissue bioaccumulation or biochemical effects. Finally, because it is expected that the adverse effect threshold will vary from species to species within any particular taxonomic group, TRVs which are protective of the more sensitive species are preferred.

Three different secondary sources were identified which provided wildlife TRVs that were derived taking each of the above factors into consideration. Each of these sources is described briefly below.

USEPA (2003)

Wildlife TRVs for several chemicals have been derived for the calculation of USEPA Ecological Soil Screening Levels (Eco-SSLs). One mammalian and one avian TRV expressed as mg contaminant per kg body weight (mg/kg BW/d) were derived based on specific standard operating procedures (SOPs) for performing literature searches, data review and extraction, and TRV derivation (USEPA, 2003). After an extensive literature search, relevant toxicity papers were "coded" into a web-based database. As part of the coding process, a NOAEL and LOAEL TRV were selected for each toxicity endpoint from each study. Each selected TRV was also assigned an overall score for ten data/study quality criteria (highest score = 100). To ensure that low quality studies were excluded from the TRV derivation process, the Eco-SSL TRV was derived from those endpoints that had an overall score higher than 65.

The derived TRV was, in most cases, the geometric mean of all No Observed Adverse Effect Levels (NOAELs) for growth and reproductive effects or the highest bounded NOAEL below the lowest bounded Lowest Observed Adverse Effect Level (LOAEL) for growth, reproduction or survival. A single bird TRV and mammal TRV was derived which represents the highest no effect level below the level which effects are first observed across multiple species and endpoints. Table B-3 provides the mammal and bird Eco-SSL TRVs for inorganic chemicals.

Engineering Field Activity West (1998)

Engineering Field Activity West (1998) developed wildlife TRVs for the purposes of conducting ecological risk assessments at Naval facilities in California. The Navy, in consultation with the USEPA Region 9 Biological Technical Advisory Group (BTAG), developed High and Low TRVs for birds and mammals. Data on ecological effects were compiled after a comprehensive literature search process. Studies focusing on test conditions similar to those expected in the field were preferred. Specific criteria included: test species similar to those expected in the field, oral exposure routes, chronic exposure durations, endpoints related to reproduction, growth, and development, study designs that deemed to be of high quality.

The High TRV was selected from the middle of the range of all sublethal effect levels across multiple studies for a particular chemical. The Low TRV was representative of a chronic no effect level and incorporated results from multiple studies. In some cases, the High and Low TRVs were derived using dose levels from the same study; in other cases, these TRVs were derived from different studies. In addition, a relative confidence level is given for each derived TRV. This confidence level provides information on whether the toxicity dataset included sensitive lifestages, included chronic exposure durations, and the number of species and receptor groups represented.

In some cases, only a High TRV could be established from the available toxicity data. Engineering Field Activity West (1998) used an uncertainty factor (UF) of 10 to estimate the Low TRV from the High TRV (ie: High/10 = Low). Although studies with chronic exposure durations were preferred, some selected studies had exposure durations that were subchronic. A UF of 10 was used to estimate the chronic TRV from a subchronic TRV (ie: subchronic/10 = chronic). Table B-4 provides the mammal and bird High TRV and Low TRV for inorganic chemicals selected in Engineering Field Activity West (1998).

Sample et al. (1996)

Sample et al. (1996) summarized available literature on the toxicity of contaminants in avian and mammalian wildlife receptors in order to calculate screening-level risk-based concentration values in water and the diet. From the toxicological literature, Sample et al. selected a single toxicity study for birds and a single toxicity study mammals and identified a LOAEL and NOAEL TRV (expressed as mg/kg BW/d). The selected study was chosen based on an evaluation of the available toxicity data, emphasizing those studies which provided information on reproductive and developmental endpoints, multiple exposure levels, and statistical comparisons to controls. In cases where toxicity data were available for multiple species, Sample et al. selected the study which provided the most conservative estimate of the TRV.

In some cases, the selected study provided only a LOAEL TRV. Sample et al. used a UF of 10 to estimate the NOAEL TRV (ie: LOAEL/10 = NOAEL). Although studies with chronic exposure durations were preferred, some selected studies had exposure durations that were subchronic. Sample et al. used a UF of 10 to estimate the chronic TRV from a subchronic TRV (ie: subchronic/10 = chronic). Table B-5 provides the mammal and bird LOAEL and NOAEL TRVs for inorganic chemicals selected by Sample et al.

For the purposes of calculating hazard quotients (HQs) for wildlife, the Eco-SSL TRVs for birds and mammals were used preferentially. If an Eco-SSL TRV was not available for a specific contaminant, then the Low TRV provided by Engineering Field Activity West (1998) was used. If a Low TRV was not available from Engineering Field Activity West (1998), the NOAEL TRV provided by Sample et al. (1996) was used.

References:

Engineering Field Activity West. 1998. Development of Toxicity Reference Values for Conducting Ecological Risk Assessment at Naval Facilities in California, Interim Final. EFA West, Naval Facilities Engineering Command. United States Navy. San Bruno, CA. September 1998.

Sample, BE, DM Opresko, GW Suter II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. Oak Ridge National Laboratory. Document Number ES/ER/TM-86/R3. June 1996.

US Environmental Protection Agency (USEPA). 2003. Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs). OSWER Directive 92857-55. Office of Solid Waste and Emergency Response. November 2003.

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Table B-1a
Surface Water Toxicity Benchmarks for Aquatic Receptors

Analyte	ACUTE				CHRONIC				
	NAWQC - Acute (ug/L) [1]	GLWQI Tier II SAV (ug/L) [2]	USEPA R4 Acute (ug/L) [2]	Surface Water Acute Benchmark (ug/L)	NAWQC - Chronic (ug/L) [1]	GLWQI Tier II SCV (ug/L) [2]	USEPA R4 - Chronic (ug/L) [2]	Other (ug/L) [2]	Surface Water Chronic Benchmark (ug/L)
Aluminum	750 [6]	--	750	750	87	--	87	--	87
Antimony	--	180	1300	180	--	30	160	--	30
Arsenic	340 [9, 10]	--	360	340	150 [9, 10]	--	190	--	150
Barium	50,000 [8]	110	--	50,000	5,000 [3]	--	--	--	5,000
Beryllium	--	35	16	35	--	0.66	0.53	--	0.66
Boron	--	30	--	30	--	1.6	--[13]	8,830 LCV Daphnids	1.60
Cadmium	2.0 [4, 10]	--	3.92	2.01	0.25 [4, 10]	--	1.1	--	0.25
Calcium	--	--	--	no benchmark	--	--	--	116,000 LCV Daphnids	116000
Chromium III	570 [4, 10]	--	1,740	570	74 [4, 10]	--	207	--	74
Chromium VI	16 [10]	--	16	16	10.6 [10]	--	11	--	11
Cobalt	--	1,500	--	1,500	--	23	--	--	23
Copper	13 [4, 10]	--	17.7	13	8.96 [4, 10]	--	11.8	--	9
Cyanide	22 [12]	--	22	22	5.2 [12]	--	5.2	5.0	5.2
Iron	--	--	--	no benchmark	1,000	--	1,000	300 CCME WQG	1,000
Lead	65 [4, 10]	--	81.6	65	2.52 [4, 10]	--	3.18	--	2.5
Magnesium	--	--	--	no benchmark	--	--	--	82,000 LCV Daphnids	82,000
Manganese	--	2,300	--	2,300	--	120	--	--	120
Mercury	1.2	--	2.4	1.2	0.65	1.3	0.012	--	0.65
Molybdenum	--	16,000	--	16,000	--	370	--	--	370
Nickel	468 [4, 10]	--	1420	468	52.0 [4, 10]	--	158	--	52
Potassium	--	--	--	no benchmark	--	--	--	53,000 LCV Daphnids	53,000
Selenium	19 [11]	--	20	19	5.0 [11]	--	5.0	--	5.0
Silver	3.4 [4, 10]	--	4.1	3.4	0.3 [3]	0.36	0.012	--	0.3
Sodium	--	--	--	no benchmark	--	--	--	680,000 LCV Daphnids	680,000
Thallium	--	110	140	110	--	12	4	--	12
Vanadium	--	280	--	280	--	20	--	--	20
Zinc	117 [4, 10]	--	117	117	118 [4, 10]	--	106	--	118

1 USEPA, 2002. National Recommended Water Quality Criteria: 2002. November 2002. EPA 822-R-02-047.
2 Suter & Tsao, 1996.
3 Only acute NAWQC available; chronic NAWQC is equal to acute / 10.
4 Metal toxicity is hardness-dependent; values shown are calculated based on a hardness of 100 mg/L.
5 National Irrigation Water Quality Program (1998)
6 Aluminum NAWQC apply to waters with pH of 6.5 - 9.0.
7 Alkalinity NAWQC is the minimum required value.
8 Based on USEPA Gold Book value.
9 NAWQC derived from data for As 3+, but is applied here to total arsenic.
10 NAWQC expressed in terms of the dissolved fraction.
11 NAWQC expressed in terms of the total recoverable fraction.
12 NAWQC expressed in terms of free cyanide.
13 Region 4 value based on minimum standard for long-term irrigation of sensitive crops.

NAWQC = National Ambient Water Quality Criteria
GLQWI = Great Lakes Water Quality Initiative
SAV/SCV = Secondary Acute/Chronic Value
CCME = Canadian Council of Ministers of the Environment
WQG = Water Quality Guidelines
LCV = Lowest Chronic Value

Table B-1b
Ambient Water Quality Criteria for Metals that are Hardness-Dependent and Freshwater Conversion Factors for the Calculation of Dissolved Fraction

Analyte	Hardness-Dependent Parameters where: *AWQCtot = exp(a * ln(H) + b)*				AWQC based on Total Recoverable (ug/L)		Total/Dissolved Conversion Factors where: *AWQCdiss = AWQCtot * [m-n*(ln(H)]*				AWQC based on Dissolved (ug/L)	
	Acute		Chronic				Acute		Chronic			
	a	b	a	b	Acute	Chronic	m	n	m	n	Acute	Chronic
Arsenic	*Not Hardness Dependent*				340	150	1.0000	0.0000	1.0000	0.0000	340	150
Cadmium	1.0166	-3.924	0.7409	-4.7190	2.1	0.27	1.1367	0.0418	1.1017	0.0418	2.0	0.25
Chromium III	0.819	3.7256	0.8190	0.6848	1803	86	0.3160	0.0000	0.8600	0.0000	570	74
Chromium VI	*Not Hardness Dependent*				16	11	0.9820	0.0000	0.9620	0.0000	16	11
Copper	0.9422	-1.7	0.8545	-1.7020	14	9	0.9600	0.0000	0.9600	0.0000	13	9
Lead	1.273	-1.46	1.2730	-4.7050	82	3.2	1.4620	0.1457	1.4620	0.1457	65	3
Mercury	*Not Hardness Dependent*				1.40	0.77	0.8500	0.0000	0.8500	0.0000	1.2	0.7
Nickel	0.846	2.255	0.8460	0.0584	469	52	0.9980	0.0000	0.9970	0.0000	468	52
Silver	1.72	-6.52	--	--	4.1	0.41	0.8500	0.0000	--	--	3	0.3
Zinc	0.8473	0.884	0.8473	0.8840	120	120	0.9780	0.0000	0.9860	0.0000	117	118

-- = not available

AWQCs are presented based on the hardness of 100 mg/L.

Sources:

USEPA, 2002. National Recommended Water Quality Criteria: 2002. US Environmental Protection Agency, Office of Water, Office of Science and Technology. November 2002. EPA 822-R-02-047.

Notes:

Silver chronic AWQC is not available; chronic AWQC is equal to the acute criterion / 10.

Table B-2
Bulk Sediment Toxicity Benchmarks for Benthic Macroinvertebrates

Analyte	Threshold Effect Concentrations (TEC)[1]					Probable Effect Concentrations (PEC)[2]				
	Consensus-Based TEC (mg/kg) [a]	ARCS TEL (mg/kg) [b]	Other (mg/kg)		Sediment Screening Benchmark (mg/kg)	Consensus-Based PEC (mg/kg) [a]	ARCS PEL (mg/kg) [b]	Other (mg/kg)		Sediment Screening Benchmark (mg/kg)
Aluminum	--	25,519	--		25,519	--	59,572	--		59,572
Antimony	--	--	2.0	NOAA ERL [c]	2.0	--	--	25.0	NOAA ERM [c]	25.0
Arsenic	9.8	11	--		9.8	33.0	48.0	--		33.0
Barium	--	--	--		no benchmark	--	--	--		no benchmark
Beryllium	--	--	--		no benchmark	--	--	--		no benchmark
Cadmium	0.99	0.58	--		1.0	4.98	3.2	--		5.0
Calcium	--	--	--		no benchmark	--	--	--		no benchmark
Chromium	43	36	--		43	111	120	--		111
Cobalt	--	--	--		no benchmark	--	--	--		no benchmark
Copper	32	28	--		32	149	100	--		149
Cyanide	--	--	--		no benchmark	--	--	--		no benchmark
Iron	--	188,400	--		188,400	--	247,600	--		247,600
Lead	36	37	--		36	128	82.0	--		128
Magnesium	--	--	--		no benchmark	--	--	--		no benchmark
Manganese	--	631	--		631	--	1,184	--		1184
Mercury	0.18	--	--		0.18	1.06	--	--		1.06
Nickel	23	20	--		23	48.6	33	--		49
Potassium	--	--	--		no benchmark	--	--	--		no benchmark
Phosphorus	--	--	--		no benchmark	--	--	--		no benchmark
Selenium	--	--	--		no benchmark	--	--	--		no benchmark
Silver	--	--	1.0	NOAA ERL [c]	1	--	--	3.7	NOAA ERM [c]	4
Sodium	--	--	--		no benchmark	--	--	--		no benchmark
Sulfide	--	--	--		no benchmark	--	--	--		no benchmark
Thallium	--	--	--		no benchmark	--	--	--		no benchmark
Vanadium	--	--	--		no benchmark	--	--	--		no benchmark
Zinc	121	98	--		121	459	540	--		459

Notes:
1 The TEC encompasses several types of sediment quality guidelines including the Lowest Effect Level (LEL), the Threshold Effect Level (TEL), the Effect Range Low (ERL), the TEL for Hyalella azetca in 28 day tests (TEL-HA28), and the Minimum Effect Threshold (MET).
2 The PEC encompasses several types of sediment quality guidelines including the Severe Effect Level (SEL), the Probable Effect Level (TEL), the Effect Range Median (ERM), the PEL for Hyalella azetca in 28 day tests (PEL-HA28), and the Toxic Effect Threshold (TET).

Sources Hierarchy:
a MacDonald et al. (2000); consensus-based threshold effect concentration (TEC) and probable effect concentration (PEC).
b Ingersoll, et al. (1996); Threshold Effect Level (TEL) and Probable Effect Level (PEL) for total extraction of sediment (BT) samples from*Hyalella azteca* 28-day
c Long and Morgan (1990); NOAA Effect Range Low (ERL) and Effect Range Median (ERM).

Table B-3
USEPA (2003) [1] Eco-SSL Toxicity Reference Values for Wildlife

Contaminant	Mammal TRV [2] (mg/kg BW/d)	Bird TRV [2] (mg/kg BW/d)
Aluminum	Narrative Statement [3]	
Antimony	0.059	Insufficient Data
Arsenic	*Pending*	*Pending*
Barium	51.8	Insufficient Data
Beryllium	0.532	Insufficient Data
Cadmium	0.770	1.47
Chromium (3+)	*Pending*	*Pending*
Chromium (6+)	*Pending*	Insufficient Data
Cobalt	7.34	7.61
Copper	*Pending*	*Pending*
Iron	Narrative Statement [4]	
Lead	4.70	1.63
Manganese	*Pending*	*Pending*
Nickel	*Pending*	*Pending*
Selenium	*Pending*	*Pending*
Silver	*Pending*	*Pending*
Vanadium	*Pending*	*Pending*
Zinc	*Pending*	*Pending*

Footnotes:

[1] See USEPA (2003) for detailed information on the derived TRV.

[2] TRV is repesentative of a high NOAEL, just below the effects threshold for endpoints related to growth, reproduction, or mortality.

[3] Aluminum is expected to be a contaminant of potential concern only when soil pH is below 5.5.

[4] Iron is an essential nutrient for wildlife, and is not expected to be a primary contaminant of concern at most sites.

Table B-4

Engineering Field Activity West (1998) Toxicity Reference Values for Wildlife

Contaminant		Mammal TRV (mg/kg BW/d) High	Mammal TRV (mg/kg BW/d) Low	Bird TRV (mg/kg BW/d) High	Bird TRV (mg/kg BW/d) Low
Arsenic	Dose [2]	4.7	0.32	22.01 [9]	5.5 [9]
	Reference	Brown et al. (1976)	Schroeder et al. (1968)	Stanley et al. (1994)	Stanley et al. (1994)
	Confidence [3]	+s +c 2/2		+s +c 1/1	
Barium	Dose	No Mammal TRV: Insufficient Data		No Bird TRV: Insufficient Data	
	Reference				
	Confidence				
Beryllium	Dose	No Mammal TRV: Insufficient Data		No Bird TRV: Insufficient Data	
	Endpoint				
	Reference				
	Confidence				
Cadmium	Dose	2.64	0.06	10.43	0.08 [1]
	Reference	Schroeder & Mitchener (1971)	Webster (1988)	Richardson et al. (1974)	Cain et al. (1983)
	Confidence	+s +c 2/2		+s +c 4/2	
Cobalt	Dose	20	1.2 [1]	No Bird TRV: Insufficient Data	
	Reference	Mollenhauer et al. (1985)	Domingo et al. (1985)		
	Confidence	+s +c 2/2			
Copper	Dose	631.58	2.67 [5,6]	52.26	2.3 [5,10]
	Reference	Hebert et al. (1993)	Pocino et al. (1991)	Jensen & Maurice (1978)	Norvell et al. (1975)
	Confidence	-s +c 2/2		+s -c 3/2	
Lead	Dose	240.64	0.0015	8.75	0.014 [1]
	Reference	Wise (1981)	Krasovskii et al. (1979)	Edens & Garlich (1983)	Edens et al. (1976); Edens & Garlich (1983)
	Confidence	+s +c 2/2		+s +c 8/4	
Manganese	Dose	159.09	13.7 [1]	776	77.6 [1]
	Reference	Gray & Laskey (1980)	Gray & Laskey (1980)	Laskey & Edens (1985)	Laskey & Edens (1985)
	Confidence	+s +c 2/2		+s -c 2/1	
Mercury [4]	Dose	4 - rodents 0.27 - lg mammals	0.25 - rodents 0.027 - lg mammals [1]	0.18	0.039 [7]
	Reference	EPA-Great Lakes; Fuyuta et al. (1978)	EPA-Great Lakes; Khera & Tabacova (1973)	EPA-Great Lakes; Heinz & Locke (1976)	EPA-Great Lakes; Heinz (1974, 1975, 1976, 1979)
	Confidence	n/a		n/a	
Molybdenum	Dose	No Mammal TRV: Insufficient Data		No Bird TRV: Insufficient Data	
	Endpoint				
	Reference				
	Confidence				

Engineering Field Activity West (1998) Toxicity Reference Values for Wildlife

Contaminant		Mammal TRV (mg/kg BW/d) High	Mammal TRV (mg/kg BW/d) Low	Bird TRV (mg/kg BW/d) High	Bird TRV (mg/kg BW/d) Low
Nickel	Dose	31.6	0.133 [1]	56.26	1.38 [5]
	Reference	Smith et al. (1993)	Smith et al. (1993)	Cain & Pafford (1981)	Cain & Pafford (1981)
	Confidence	+s +c 2/2		+s -c 2/2	
Silver	Dose	No Mammal TRV: Insufficient Data		No Bird TRV: Insufficient Data	
	Reference				
	Confidence				
Selenium	Dose	1.21	0.05	0.93	0.23
	Reference	Schroeder & Mitchener (1971)	Harr et al. (1967)	Heinz et al. (1989)	Heinz et al. (1989)
	Confidence	-s +c 2/2		+s +c 2/2	
Thallium	Dose	1.43	0.48	No Bird TRV: Insufficient Data	
	Reference	Downs et al. (1960)	Downs et al. (1960)		
	Confidence	-s -c 1/1			
Zinc	Dose	411.43	9.6 [1,6]	172	17.2 [1]
	Reference	Schlicker & Cox (1968)	Aughey et al. (1977)	Gasaway & Buss (1972)	Gasaway & Buss (1972)
	Confidence	+s +c 2/2		+s +c 3/2	

Footnotes:

[1] Uncertainty factor of 10 for low-effect to no-effect level conversion applied to arrive at low TRV.

[2] See Navy (1998) for detailed information and rationale for the selected TRV studies and full citations.

[3] Confidence interpretation:
s - does dataset include a sensitive lifestage (+ = yes, - = no);
c - does dataset include a chronic exposure duration (+ = yes, - = no)
n/n - ratio of the number of species in dataset to the number of groups represented, see Section 3.4 in Navy (1998) for a summary of groups.

[4] Mercury TRVs were selected from data in Great Lakes summary tables. See Section 5.8.2.1 in Navy (1998) for rationale behind the selection of these TRVs. Confidence ratings were not applied to these TRVs.

[5] Uncertainty factor of 10 for subchronic to chronic conversion applied to arrive at low TRV.

[6] Low TRV was adjusted for or is close to nutritional requirements.

[7] EPA applied to the dose an uncertainty factor of 2 for low-effect to no-effect conversion.

[9] The diversity of test organisms in the cadmium data was limited. The workgroup had high confidence in the TRV for waterfowl, but lower confidence if the TRV is applied to other birds.

[10] The workgroup considered this TRV to be very conservative for granivorous birds.

Engineering Field Activity West (1998) Toxicity Reference Values for Wildlife

High TRV Endpoint Descriptions:

Arsenic, Mammal - Decrease in water intake, kidney:body weight ratio, respiration parameters. High TRV in mid-range of effects, but below LD50s from ATSDR toxicity profiles (8-10 mg/kg/d).

Arsenic, Bird - Decrease in liver weight, whole egg weight, duckling body weight and liver weight post-hatching, growth rate, production; Increase in glycogen depletion, number of days between pairing and first egg. High TRV in mid-range of effects.

Cadmium, Mammal - Increase in young deaths and runts in F1 and F2 generations; Failure to breed in F2B generation. High TRV in mid-range of effects.

Cadmium, Bird - Decrease in body and testis weight, hematocrit, and hemoglobin; Increase in heartt weight; Histological changes in liver, duodenum, bone marrow, adrenal. High TRV in mid-range of reproductive effects.

Cobalt, Mammal - Increase in testicular degeneration. High TRV in mid-range of reported effects on ecologically relevant endpoints.

Copper, Mammal - Decreased water consumption, body weight, and increased mortality. High TRV in mid-range of effects.

Copper, Bird - Increase in gizzard erosion and feed to gain ratio, increase in relative gizzard and proventriculus weight. High TRV in mid-range of effects.

Lead, Mammal - Decrease in body weight, liver weight, and kidney weight. High TRV in mid-range of effects.

Lead, Bird -Decrease in egg production. High TRV in mid-range of effects.

Manganese, Mammal - Decrease in paired testes weight, seminal vesicle weight, and preputial gland weight. High TRV in mid-range of effects.

Manganese, Bird - Decrease in rate of motor development and aggressive behavior. High TRV was at the high end of the range of effects, but was chosen because of corroborating data in Southern and Baker (1983).

Mercury, Mammal - Anorexia, ataxia, and death (LOAEL). Magnitude of effect not noted.

Mercury, Bird- Reproductive effects in mallards (LOAEL). Magnitude of effect not noted.

Nickel, Mammal - Increase in number and proportion of pups born dead or dying shortly after birth during G1; increase in food consumption and decrease in water intake in dams. High TRV was in mid-range of adverse effects.

Nickel, Bird - Decrease in length:weight ratio of humerus at 30 days. High TRV in mid-range of systemic effects.

Selenium, Mammal - Increase in F1 generation of young deaths and the number of runts; F2 generation had a significant increase in the number of runts; F3 generation had a significant increase in the number of runts. High TRV in mid-range of effects.

Selenium, Bird - Decrease in hatching success. High TRV in mid-range of effects.

Thallium, Mammal - Increase in hair loss. High TRV below mortality effect and in mid-range of effects.

Zinc, Mammal - Decreased fetus weight, fetal liver weight, and body weight; total resorption of fetus (LOAEL). High TRV in mid-range of effects.

Zinc, Bird - Decrease in body weight at 40 days; decrease in gonad weight; decrease in organ:body weight ratio (pancreas, adrenal and kidney); decreases in pancreas weight and liver weight, leg paralysis, diarrhea. High TRV based on effect level in Gasaway and Bus (1972).

Table B-5
Sample et al. (1996) Toxicity Reference Values for Wildlife

Contaminant		Mammal TRV (mg/kg BW/d) LOAEL	Mammal TRV (mg/kg BW/d) NOAEL	Bird TRV (mg/kg BW/d) LOAEL	Bird TRV (mg/kg BW/d) NOAEL
Aluminum	Dose [1]	19.3	1.93 [2]	--	109.7
	Reference	Ondreicka et al. (1966)		Carriere et al. (1986)	
Antimony	Dose	1.25	0.125 [2]	No Bird TRV: Insufficient Data	
	Reference	Schroeder et al. (1968b)			
Arsenic	Dose	1.26	0.126 [2]	12.84	5.14
	Reference	Schroeder & Mitchener (1971)		USFWS (1964)	
Barium	Dose	19.8 [3]	5.1	41.7 [3]	20.8 [3]
	Reference	Borzelleca et al. (1988)	Perry et al. (1983)	Johnson et al. (1960)	
Beryllium	Dose	--	0.66	No Bird TRV: Insufficient Data	
	Reference	Schroeder & Mitchener (1975)			
Boron	Dose	93.6	28	100	28.8
	Reference	Weir & Fisher (1972)		Smith & Anders (1989)	
Cadmium	Dose	10	1	20	1.45
	Reference	Sutou et al. (1980b)		White & Finley (1978)	
Chromium (3+)	Dose	--	2737	5	1
	Reference	Ivankovic & Preussmann (1975)		Haseltine et al., unpubl. Data	
Chromium (6+)	Dose	13.14 [3]	3.28	No Bird TRV: Insufficient Data	
	Reference	Steven et al. (1976)	MacKenzie et al. (1958)		
Copper	Dose	15.14	11.7	61.7	47
	Reference	Aulerich et al. (1982)		Mehring et al. (1960)	
Cyanide	Dose	--	68.7	No Bird TRV: Insufficient Data	
	Reference	Tewe & Maner (1981)			
Fluoride	Dose	52.75	31.37	32	7.8
	Reference	Aulerich et al. (1987)		Pattee et al. (1988)	
Lead	Dose	80	8	11.3	1.13
	Reference	Azar et al. (1973)		Edens et al. (1976)	
Lithium	Dose	18.8	9.4	No Bird TRV: Insufficient Data	
	Reference	Marathe & Thomas (1986)			
Manganese	Dose	284	88	--	977
	Reference	Laskey et al. (1982)		Laskey & Edens (1985)	
Mercury, inorganic	Dose	--	1	0.9	0.45
	Reference	Aulerich et al. (1974)		Hill & Schaffner (1976)	
Mercury, organic	Dose	mink - 0.025 [3] rat - 0.16	mink - 0.015 [3] rat - 0.032	0.064	0.0064 [2]
	Reference	mink - Wobeser et al. (1976) rat - Verschuuren et al. (9176)		Heinz (1979)	
Molybdenum	Dose	2.6	0.26 [2]	35.3	3.5 [2]
	Reference	Schroeder & Mitchener (1971)		Lepore & Miller (1965)	

Sample et al. (1996) Toxicity Reference Values for Wildlife

Contaminant		Mammal TRV (mg/kg BW/d) LOAEL	Mammal TRV (mg/kg BW/d) NOAEL	Bird TRV (mg/kg BW/d) LOAEL	Bird TRV (mg/kg BW/d) NOAEL
Nickel	Dose	80	40	107	77.4
	Reference	Ambrose et al. (1976)		Cain & Pafford (1981)	
Selenium, inorganic	Dose	No Mammal TRV: Insufficient Data		1	0.5
	Reference			Heinz et al. (1987)	
Selenium, organic	Dose	No Mammal TRV: Insufficient Data		0.8	0.4
	Reference			Heinz et al. (1989) [4]	
Thallium	Dose	0.074 [3]	0.0074 [2,3]	No Bird TRV: Insufficient Data	
	Reference	Formigli et al. (1986)			
Vanadium	Dose	2.1	0.21 [2]	--	11.4
	Reference	Domingo et al. (1986)		White & Dieter (1978)	
Zinc	Dose	320	160	131	14.5
	Reference	Schlicker & Cox (1968)		Stahl et al. (1990)	

Footnotes:

[1] See Sample et al. (1996) for detailed information on the selected TRV studies and full citations.

[2] A NOAEL was estimated by dividing the LOAEL by a factor of 10.

[3] A chronic TRV was estimated by dividing the subchronic TRV by a factor of 10.

[4] Toxicity data for selenomethionine were provided for the mallard duck, screech owl, and black-crowned night heron. Toxicity data for the most sensitive species (mallard duck) are presented in this table.

Sample et al. (1996) Toxicity Reference Values for Wildlife

LOAEL TRV Endpoint Descriptions:

Aluminum, Mammal - (Reproduction) Exposed during critical lifestage. Decrease in growth of F2 and F3 generations. Magnitude of the effect not noted.

Antimony, Mammal - (Lifespan, Longevity) Decrease in female median lifespan. Magnitude of the effect not noted.

Arsenic, Mammal - (Reproduction) Exposed during critical lifestage. Decline in litter size with each successive generation over 3 generations. Magnitude of the effect not noted.

Arsenic, Bird - (Mortality) Magnitude of the effect not noted.

Barium, Mammal - (Mortality) 30% mortality to female rats at 300 mg/kg/d $BaCl_2$. Magnitude of the effect not noted.

Barium, Bird - (Mortality) Magnitude of the effect not noted.

Boron, Mammal - (Reproduction) Exposed during critical lifestage. Sterility. Magnitude of the effect not noted.

Boron, Bird - (Reproduction) Exposed during critical lifestage. Reduced egg fertility; decrease in duckling growth; increase in embryo and duckling mortality. Magnitude of the effect not noted.

Cadmium, Mammal - (Reproduction) Exposed during critical lifestage. Decrease in fetal implantations and fetal survivorship; increase in fetal resorptions. Magnitude of the effect not noted.

Cadmium, Bird - (Reproduction) Exposed during critical lifestage. Decrease in egg production. Magnitude of the effect not noted.

Chromium (3+), Bird - (Reproduction) Exposed during critical lifestage. Decrease in duckling survival. Magnitude of the effect not noted.

Chromium (6+), Mammal - (Mortality) Magnitude of the effect not noted.

Copper, Mammal - (Reproduction) Exposed during critical lifestage. Decreased survival of mink kits. Magnitude of the effect not noted.

Copper, Bird - (Growth, Mortality) Decrease in growth of day old chicks and increased mortality. Magnitude of effect not noted.

Fluoride, Mammal - (Reproduction) Exposed during critical lifestage. Survivorship of kits significantly reduced. Magnitude of the effect not noted.

Fluoride, Bird - (Reproduction) Exposed during critical lifestage. Decrease in fertility and hatching success. Magnitude of the effect not noted.

Lead, Mammal - (Reproduction) Exposed during critical lifestage. Decrease in offspring weight; kidney damage in young. Magnitude of the effect not noted.

Lead, Bird - (Reproduction) Exposed during critical lifestage. Decrease in egg hatching success. Magnitude of the effect not noted.

Lithium, Mammal - (Reproduction) Exposed during critical lifestage. Decrease in nmber of offspring and offspring weights. Magnitude of the effect not noted.

Manganese, Mammal - (Reproduction) Exposed during critical lifestage. Decrease in pregnancy percentage and fertility. Magnitude of the effect not noted.

Mercury (Inorganic), Bird - (Reproduction) Exposure during a reproduction. Increase in egg production; decrease in fertility and hatchability. Magnitude of the effect not noted.

Mercury (Organic), Mammal - (Mortality, weight loss, ataxia) Mink. (Reproduction) Rat, exposed during critical lifestage; decrease in pup viability. Magnitude of the effect not noted.

Mercury (Organic), Bird - (Reproduction) Exposed during critical lifestage. Decrease in egg and duckling production. Magnitude of the effect not noted.

Molybdenum, Mammal - (Reproduction) Exposed during critical lifestage. Decrease reproductive success; increase incidence of runts. Magnitude of the effect not noted.

Molybdenum, Bird - (Reproduction) Exposed during critical lifestage. Embryonic viability reduced to zero. Magnitude of the effect not noted.

Nickel, Mammal - (Reproduction) Exposed during critical lifestage. Decrease in offspring body weight. Magnitude of the effect not noted.

Nickel, Bird - (Mortality, growth, behavior) Increase mortality, decreased growth. Magnitude of the effect not noted.

Selenium (Inorganic), Bird - (Reproduction) Exposed during critical lifestage. Increase in frequence of lethally deformed embryos. Magnitude of the effect not noted.

Selenium (Organic), Bird - (Reproduction) Exposed during critical lifestage. Decrease in duckling survival. Magnitude of the effect not noted.

Thallium, Mammal - (Reproduction) Decrease in sperm motility. Magnitude of the effect not noted.

Vanadium, Mammal - (Reproduction) Exposed during critical lifestage. Increase in number of dead young/litter, decrease in size and weight of offspring. Magnitude of the effect not noted.

Zinc, Mammal - (Reproduction) Exposed during critical lifestage. Increase in rate of fetal resorption; decrease in fetal growth rate. Magnitude of the effect not noted.

Zinc, Bird - (Reproduction) Exposed during critical lifestage. Decrease in egg hatchability. Magnitude of the effect not noted.

APPENDIX C

Species-Specific Toxicity Values for Direct Contact with Water

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ANTIMONY
(freshwater data only)

ACUTE TOXICITY DATA

Class	Species	SMAV (ug/L) Total		Acute Value/2 (ug/L)
INVERT.	Hydra, Hydra oligactis		500	250
INVERT.	Cladoceran, Ceriodaphnia dubia		3,470	1,735
INVERT.	Cladoceran, Daphnia magna		18,140	9,070
INVERT.	Amphipod, Gammarus pseudolimnaeus	>	25,700	12,850
INVERT.	Caddisfly (larvae), Pysnopsyche sp.	>	25,700	12,850
FISH	Rainbow trout (fry), Salmo gairdneri	>	25,700	12,850
FISH	Fathead minnow (8 wk), Pimephales promelas		21,800	10,900
FISH	Bluegill, Lepomis macrochirus	>	25,800	12,900

Source: Draft AWQC, Table 1 (USEPA 1988)

CHRONIC TOXICITY DATA

Class	Species	SMCV (ug/L) Total	Chronic Value (ug/L)
INVERT.	Daphnia magna	3,218	3,218
FISH	Fathead minnow, Pimephales promelas	1,616	1,616

Source: Draft AWQC, Table 2 (USEPA 1988)

ARSENIC III
(freshwater data only)

RANKED ACUTE TOXICITY DATA FOR INVERTEBRATES

Rank	Class	Species	Total (ug/L) SMAV	Total (ug/L) GMAV	Dissolved (ug/L) SMAV	Dissolved (ug/L) GMAV	Dissolved (ug/L) SMAV/2	Dissolved (ug/L) GMAV/2
14	INVERT.	Midge, Tanytarsus dissimilis	97000	97,000	97000	97,000	48500	48,500
11	INVERT.	Snail, Aplexa hypnorum	24500	24,500	24500	24,500	12250	12,250
10	INVERT.	Stonefly, Pteronarcys californica	22040	22,040	22040	22,040	11020	11,020
4	INVERT.	Cladoceran, Daphnia magna	4449	2,690	4449	2,690	2224.5	1,345
	INVERT.	Cladoceran, Daphnia pulex	1626		1626		813	
3	INVERT.	Cladoceran, Ceriodaphnia reticulata	1511	1,511	1511	1,511	755.5	756
2	INVERT.	Cladoceran, Simocephalus serrulatus	812	1,175	812	1,175	406	588
	INVERT.	Cladoceran, Simocephalus vetulus	1700		1700		850	
1	INVERT.	Amphipod, Gammarus pseudolimnaeus	874	874	874	874	437	437

Source: 1995 Updates, Table N3 (USEPA, 1995)

CHRONIC TOXICITY DATA FOR INVERTEBRATES

Rank	Class	Species	Total (ug/L) SMAV	Total (ug/L) GMAV	Dissolved (ug/L) SMAV	Dissolved (ug/L) GMAV
1	INVERT.	Cladoceran, Daphnia magna (ACR=4.748)	937	567	937	567

Source: 1995 Updates, Table N3 (USEPA, 1995)
Values derived from Acute-Chronic Ratio (ACR)

CADMIUM

(freshwater data only)

RANKED ACUTE TOXICITY DATA			Total (ug/L)				Dissolved (ug/L)					
			Hardness = 50 mg/L		Hardness = 100 mg/L		Hardness = 50 mg/L		Hardness = 100 mg/L			
Rank	Class	Species	SMAV	GMAV	SMAV	GMAV	SMAV	GMAV	SMAV	GMAV	SMAV/2	GMAV/2
55	INVERT.	Midge, Chironomus riparius	96,880	96,880	196,002	196,002	94,264	94,264	185,026	185,026	92,513	92,513
54	INVERT.	Planarian, Dendrocoelum lacteum	14,067	14,067	28,460	28,460	13,687	13,687	26,866	26,866	13,433	13,433
53	INVERT.	Crayfish, Orconectes virilis	11,859	> 11,683	23,992	23,636	11,539	11,368	22,649	22,313	11,324	11,156
	INVERT.	Crayfish, Orconectes immunis	> 11,509		23,284		11,198		21,980		10,990	
52	FISH	Tilapia, Oreochromis mossambica	10,663	10,663	21,573	21,573	10,375	10,375	20,365	20,365	10,182	10,182
51	FISH	Mosquitofish, Gambusia affinis	6,499	6,499	13,148	13,148	6,324	6,324	12,412	12,412	6,206	6,206
50	INVERT.	Tubificid worm, Rhyacodrilus montana	6,169	6,169	12,481	12,481	6,002	6,002	11,782	11,782	5,891	5,891
49	FISH	Threespine stickleback, Gasterosteus aculeatus	5,439	5,439	11,004	11,004	5,292	5,292	10,388	10,388	5,194	5,194
48	INVERT.	Tubificid worm, Stylodrilus heringianus	5,386	5,386	10,897	10,897	5,241	5,241	10,286	10,286	5,143	5,143
47	*FISH*	*Channel catfish, Ictalurus punctatus*	*5,055*	*5,055*	*10,227*	*10,227*	*4,919*	*4,919*	*9,654*	*9,654*	4,827	4,827
46	FISH	Common carp,Cyprinus carpio	4,238	4,238	8,574	8,574	4,124	4,124	8,094	8,094	4,047	4,047
45	FISH	Green sunfish, Lepomis cyanellus	2,965	4,228	5,999	8,554	2,885	4,114	5,663	8,075	2,831	4,037
	FISH	Bluegill, Lepomis macrochirus	6,028		12,196		5,865		11,513		5,756	
44	INVERT.	Tubificid worm, Spirosperma ferox	3,427	3,886	6,933	7,862	3,334	3,781	6,545	7,422	3,273	3,711
	INVERT.	Tubificid worm, Spirosperma nikolskyi	4,406		8,914		4,287		8,415		4,207	
43	FISH	Red shiner, Notropis lutrenis	3,837	3,837	7,763	7,763	3,733	3,733	7,328	7,328	3,664	3,664
42	INVERT.	Tubificid worm, Varichaeta pacifica	3,721	3,721	7,528	7,528	3,621	3,621	7,107	7,107	3,553	3,553
41	FISH	White sucker, Catostomus commersoni	3,136	3,136	6,345	6,345	3,051	3,051	5,989	5,989	2,995	2,995
40	INVERT.	Tubificid worm, Quistradilus multisetosus	3,133	3,133	6,339	6,339	3,048	3,048	5,984	5,984	2,992	2,992
39	FISH	Flagfish, Jordanella floridae	2,847	2,847	5,760	5,760	2,770	2,770	5,437	5,437	2,719	2,719
38	FISH	Guppy, Poecilia reticulata	2,462	2,462	4,981	4,981	2,396	2,396	4,702	4,702	2,351	2,351
37	INVERT.	Tubificid worm, Branchiura sowerbyi	2,350	2,350	4,754	4,754	2,287	2,287	4,488	4,488	2,244	2,244
36	INVERT.	Mayfly, Ephemerella grandis	2,278	2,278	4,609	4,609	2,216	2,216	4,351	4,351	2,175	2,175
35	INVERT.	Crayfish, Procambarus clarkii	1,748	1,748	3,536	3,536	1,701	1,701	3,338	3,338	1,669	1,669
34	INVERT.	Amphipod, Crangonyx pseudogracilis	1,700	1,700	3,439	3,439	1,654	1,654	3,247	3,247	1,623	1,623
33	AMPHIB.	African clawed frog, Xenopus laevis	1,529	1,529	3,093	3,093	1,488	1,488	2,920	2,920	1,460	1,460
32	INVERT.	Tubificid worm, Tubifex tubifex	1,361	1,361	2,754	2,754	1,324	1,324	2,599	2,599	1,300	1,300
31	FISH	Goldfish, Carassius auratus	844	844	1,708	1,708	821	821	1,612	1,612	806	806
30	INVERT.	Tubificid worm, Limnodrilus hoffmeisteri	775	775	1,568	1,568	754	754	1,480	1,480	740	740
29	AMPHIB.	Salamander, Ambystoma gracile	521	521	1,055	1,055	507	507	996	996	498	498
28	INVERT.	Isopod, Asellus bicrenata	472	472	955	955	459	459	902	902	451	451
27	INVERT.	Bryozoan, Plumatella emarginata	260	260	525	525	253	253	496	496	248	248
26	INVERT.	Cladoceran, Alona affinis	247	247	500	500	241	241	472	472	236	236
25	INVERT.	Copepod, Cyclops varicans	223	223	452	452	217	217	426	426	213	213
24	INVERT.	Leech, Glossiponia complanta	193	193	389	389	187	187	368	368	184	184
23	INVERT.	Bryozoan, Pectinatella magnifica	167	167	337	337	162	162	319	319	159	159
22	INVERT.	Worm, Lumbriculus variegatus	131	131	264	264	127	127	249	249	125	125
21	INVERT.	Snail, Aplexa hypnorum	104	104	210	210	101	101	198	198	99	99
20	INVERT.	Snail, Physa gyrina	100	100	203	203	97.5	97.5	191.4	191.4	95.7	95.7
19	INVERT.	Amphipod, Gammarus pseudolimnaeus	78.7	78.7	159	159	76.6	76.6	150.3	150.3	75.1	75.1
18	INVERT.	Isopod, Lirceus alabamae	48.4	48.4	98.0	98.0	47.1	47.1	92.5	92.5	46.3	46.3
17	*INVERT.*	*Cladoceran, Moina macrocopa*	*43.1*	*43.1*	*87.2*	*87.2*	*41.9*	*41.9*	*82.3*	*82.3*	*41.1*	*41.1*
16	INVERT.	Mussel, Utterbackia imbecilis	42.9	42.9	86.8	86.8	41.8	41.8	82.0	82.0	41.0	41.0
15	FISH	Bonytail, Gila elegans	38.7	38.7	78.3	78.3	37.7	37.7	73.9	73.9	37.0	37.0
14	FISH	Razorback sucker, Xyrauchen texanus	36.6	36.6	74.1	74.1	35.6	35.6	69.9	69.9	35.0	35.0
13	INVERT.	Cladoceran, Ceriodaphnia dubia	31.4	35.9	63.5	72.6	30.5	34.9	59.9	68.6	30.0	34.3
	INVERT.	Cladoceran, Ceriodaphnia reticulata	41.1		83.1		40.0		78.4		39.2	
12	INVERT.	Bryozoan, Lophopodella carteri	35.7	35.7	72.3	72.3	34.8	34.8	68.3	68.3	34.1	34.1
11	INVERT.	Mussel, Vilosa vibex	35.2	35.2	71.2	71.2	34.2	34.2	67.2	67.2	33.6	33.6
10	INVERT.	Mussel, Actinonaia pectorosa	33.8	33.8	68.4	68.4	32.9	32.9	64.6	64.6	32.3	32.3
9	INVERT.	Mussel, Lampsilis straminea claibornensis	47.7	33.8	96.5	68.3	46.4	32.8	91.1	64.5	45.5	32.2
	INVERT.	Mussel, Lampsilis teres	23.9		48.4		23.3		45.6		22.8	
8	INVERT.	Cladoceran, Simocephalus serrulatus	30.2	30.2	61.1	61.1	29.4	29.4	57.7	57.7	28.8	28.8
7	FISH	Fathead minnow, Pimephales promelas	29.2	29.2	59.1	59.1	28.4	28.4	55.8	55.8	27.9	27.9
6	INVERT.	Cladoceran, Daphnia magna	13.4	24.9	27.1	50.4	13.0	24.3	25.6	47.6	12.8	23.8
	INVERT.	Cladoceran, Daphnia pulex	46.4		93.8	0.0	45.1		88.5		44.3	
5	FISH	Colorado squawfish, Ptychocheilus lucius	22.5	22.5	45.6	45.6	21.9	21.9	43.0	43.0	21.5	21.5
	FISH	Northern pike minnow, Ptychocheilus oregonensis	~~2,221~~		~~4,493~~		~~2,161~~		~~4,242~~		~~2,121~~	
4	FISH	Coho salmon, Oncorhynchus kisutch	6.22	3.84	12.6	7.76	6.05	3.73	11.88	7.33	5.94	3.66
	FISH	Chinook salmon, Oncorhynchus tshawytscha	4.31		8.71		4.19		8.22		4.11	
	FISH	Rainbow trout, Oncorhynchus mykiss	2.11		4.26		2.05		4.03		2.01	
3	FISH	Striped bass, Morone saxatilis	2.93	2.93	5.92	5.92	2.85	2.85	5.59	5.59	2.79	2.79
2	FISH	Brook trout, Salvelinus fontinalis	< 1.79	< 1.96	3.62	3.97	1.74	1.91	3.42	3.75	1.71	1.87
	FISH	Bull trout, Salvelinus confluentus	2.15		4.35		2.09		4.11		2.05	
1	FISH	Brown trout, Salmo trutta	1.61	1.61	3.26	3.26	1.57	1.57	3.08	3.08	1.54	1.54

Source: Table 3a, Cadmium AWQC Update (USEPA, 2001)

Acute TRV at Hardness = 50 mg/L:	1.05
Acute TRV at Hardness = 100 mg/L:	2.13
TRV @ H=100 / TRV @ H=50:	**2.02**

CADMIUM
(freshwater data only)

RANKED CHRONIC TOXICITY DATA			Total (ug/L)				Dissolved (ug/L)			
			Hardness = 50 mg/L		Hardness = 100 mg/L		Hardness = 50 mg/L		Hardness = 100 mg/L	
Rank	Class	Species	SMCV	GMCV	SMCV	GMCV	SMCV	GMCV	SMCV	GMCV
16	INVERT.	Cladoceran, Ceriodaphnia dubia	27.17	27.17	45.41	45.41	25.49	25.49	41.27	41.27
15	FISH	Blue Tilapia, Oreochromis aurea	> 23.63	> 23.63	39.49	39.49	22.16	22.16	35.90	35.90
14	INVERT.	Oligochaete, Aeolosoma headleyi	20.74	20.74	34.66	34.66	19.45	19.45	31.51	31.51
13	FISH	Bluegill, Lepomis macrochirus	17.38	17.38	29.05	29.05	16.30	16.30	26.40	26.40
12	FISH	Fathead minnow, Pimephales promelas	16.38	16.38	27.37	27.37	15.36	15.36	24.88	24.88
11	FISH	Smallmouth bass, Micropterus dolomieui	8.12	8.12	13.58	13.58	7.62	7.62	12.34	12.34
10	FISH	Northern pike, Esox lucius	8.09	8.09	13.52	13.52	7.59	7.59	12.29	12.29
9	FISH	White sucker, Catostomus commersoni	7.80	7.80	13.04	13.04	7.32	7.32	11.86	11.86
	FISH	Atlantic salmon, Salmo salar	7.92		13.24		7.43		12.03	
8	FISH	Brown trout, Salmo trutta	5.00	6.30	8.36	10.52	4.69	5.91	7.60	9.56
7	FISH	Flagfish, Jordanella floridae	5.32	5.32	8.89	8.89	4.99	4.99	8.08	8.08
6	INVERT.	Snail, Aplexa hypnorum	4.82	4.82	8.06	8.06	4.52	4.52	7.32	7.32
5	FISH	Brook trout, Salvelinus fontinalis	2.64	4.62	4.42	7.73	2.48	4.34	4.02	7.02
	FISH	Lake trout, Salvelinus namaycush	8.09		13.52		7.59		12.29	
4	INVERT.	Midge, Chironomus tentans	2.80	2.80	4.69	4.69	2.63	2.63	4.26	4.26
3	FISH	Coho salmon, Oncorhynchus kisutch	4.27	2.44	7.13	4.08	4.00	2.29	6.48	3.71
	FISH	Rainbow trout, Oncorhynchus mykiss	1.31		2.19		1.23		1.99	
	FISH	Chinook salmon, Oncorhynchus tshawytscha	2.61		4.37		2.45		3.97	
2	INVERT.	Cladoceran, Daphnia magna	< 0.38	< 0.38	0.63	0.63	0.36	0.36	0.58	0.58
	INVERT.	Cladoceran, Daphnia pulex	~~6.17~~		~~10.31~~		~~5.78~~		~~9.37~~	
1	INVERT.	Amphipod, Hyalella azteca	0.27	0.27	0.46	0.46	0.26	0.26	0.42	0.42

Source: Table 3c, Cadmium AWQC Update (USEPA, 2001)

Chronic TRV at Hardness = 50 mg/L:	0.16
Chronic TRV at Hardness = 100 mg/L:	0.27
TRV @ H=100 / TRV @ H=50:	**1.67**

LEAD
(freshwater data only)

RANKED ACUTE TOXICITY DATA			Total (ug/L)				Dissolved (ug/L)					
			Hardness = 50 mg/L		Hardness = 100 mg/L		Hardness = 50 mg/L		Hardness = 100 mg/L			
Rank	Class	Species	SMAV	GMAV	SMAV	GMAV	SMAV	GMAV	SMAV	GMAV	SMAV/2	GMAV/2
10	INVERT.	Midge, Tanytarsus dissimilis	235,900	235,900	570,084	570,084	210,423	210,423	450,938	450,938	225,469	225,469
9	FISH	Goldfish, Carassius auratus	101,100	101,100	244,322	244,322	90,181	90,181	193,259	193,259	96,629	96,629
8	FISH	Guppy, Poecilia reiculata	66,140	66,140	159,836	159,836	58,997	58,997	126,431	126,431	63,215	63,215
7	FISH	Bluegill, Lepomis macrochirus	52,310	52,310	126,414	126,414	46,661	46,661	99,994	99,994	49,997	49,997
6	FISH	Fathead minnow, Pimephales promelas	25,440	25,440	61,479	61,479	22,693	22,693	48,630	48,630	24,315	24,315
5	FISH	Brook trout, Salvelinus fontinalis	4,820	4,820	11,648	11,648	4,299	4,299	9,214	9,214	4,607	4,607
4	FISH	Rainbow trout, Salmo gairdneri	2,448	2,448	5,916	5,916	2,184	2,184	4,680	4,680	2,340	2,340
3	INVERT.	Snail, Aplexa hypnorum	1,040	1,040	2,513	2,513	928	928	1,988	1,988	994	994
2	INVERT.	Cladoceran, Daphnia magna	448	448	1,082	1,082	399	399	856	856	428	428
1	INVERT.	Amphipod, Gammarus pseudolimnaeus	143	143	345	345	127	127	273	273	136	136

Source: Table 3, Lead AWQC (USEPA, 1984)

Acute TRV at Hardness = 50 mg/L:	33.78
Acute TRV at Hardness = 100 mg/L:	81.65
TRV @ H=100 / TRV @ H=50:	**2.42**

RANKED CHRONIC TOXICITY DATA			Total (ug/L)				Dissolved (ug/L)			
			Hardness = 50 mg/L		Hardness = 100 mg/L		Hardness = 50 mg/L		Hardness = 100 mg/L	
Rank	Class	Species	SMCV	GMCV	SMCV	GMCV	SMCV	GMCV	SMCV	GMCV
3	FISH	Brook trout, Salvelinus fontinalis (ACR=49.35)	98	98	236	236	87	87	187	187
2	FISH	Rainbow trout, Salmo gairdneri (ACR=61.97)	40	40	95	95	35	35	76	76
1	INVERT.	Cladoceran, Daphnia magna (ACR=18.13)	25	25	60	60	22	22	47	47

Source: Table 3, Lead AWQC (USEPA, 1984)
Values derived from Acute-Chronic Ratio (ACR)

Chronic TRV at Hardness = 50 mg/L:	1.32
Chronic TRV at Hardness = 100 mg/L:	3.18
TRV @ H=100 / TRV @ H=50:	**2.42**

MANGANESE
(freshwater data only)

ACUTE TOXICITY DATA

Class	Species	SMAV (ug/L) Total	Acute Value/2 (ug/L)
INVERT.	Isopod, Asellus aquaticus	333,000	166,500
INVERT.	Amphipod, Crangonyx pseudogracilis	694,000	347,000
INVERT.	Cladoceran, Daphnia magna	19,350	9,675
FISH	*Fathead minnow, Pimephales promelas*	33,600	16,800

Source: Table A.1, Suter & Tsao (1996)

CHRONIC TOXICITY DATA

Class	Species	SMCV (ug/L) Total	Chronic Value (ug/L)
FISH	Fathead minnow, Pimephales promelas	1,775	1,775

Source: Table A.1, Suter & Tsao (1996)

SELENIUM
(freshwater data only)

ACUTE TOXICITY DATA

Class	Species	SMAV (ug/L) Total	Acute Value/2 (ug/L)
BMI	Leech, Nephelopsis obscure	203,000	101,500
BMI	Midge, Tanytarsus dissimilis	42,500	21,250
BMI	Snail, Aplexa hypnoum	34,910	17,455
BMI	Midge, Chironomus plumosus	25,934	12,967
BMI	Snail, Physa sp.	24,100	12,050
BMI	Amphipod, Gammarus pseudolimnaeus	2,704	1,352
INVERT.	Cladoceran, Daphnia sp.	1,796	898
INVERT.	Hydra, Hydra sp.	1,700	850
INVERT.	Cladoceran, Ceriodaphnia affinis	< 603.6	302
INVERT.	Amphipod, Hyalella azteca	340	170
FISH	Common carp, Cyprinus carpio	35,000	17,500
FISH	White sucker, Castostomus commersoni	30,176	15,088
FISH	Bluegill, Lepomis macrochirus	28,500	14,250
FISH	Channel catfish, Ictalurus punctatus	13,600	6,800
FISH	Mosquitofish, Gambusia affinis	12,600	6,300
FISH	Yellow perch, Perca flavenscens	11,700	5,850
FISH	Rainbow trout, Oncorhynchus mykiss	10,490	5,245
FISH	Brook trout, Salvelinus fontinalis	10,200	5,100
FISH	Flagfish, Jordanella floridae	6,500	3,250
FISH	Striped bass, Morone saxatilis	1,783	892
FISH	Fathead minnow, Pimephales promelas	1,601	801

Source: 1995 Updates, Table N2 (USEPA, 1995)

CHRONIC TOXICITY DATA

Class	Species	Tox. Value (ug/L) Total	Chronic Value (ug/L)
FISH	Field study - severe effects in fish from food chain accumulation	10	-
FISH	Field study - no apparent effects in fish from food chain accumulation	5	5

Source: Selenium AWQC (USEPA, 1987)

THALLIUM
(freshwater data only)

ACUTE TOXICITY DATA

Class	Species	SMAV (ug/L) Total	Acute Value/2 (ug/L)
INVERT.	Cladoceran, Daphnia magna	905	453
FISH	Bluegill, Lepomis macrochirus	125,900	62,950
FISH	Fathead minnow, Pimephales promelas	1,795	898

Source: Table A.1, Suter & Tsao (1996)

CHRONIC TOXICITY DATA

Class	Species	SMCV (ug/L) Total	Chronic Value (ug/L)
INVERT.	Cladoceran, Daphnia magna	135	135
FISH	Fathead minnow, Pimephales promelas	57	57

Source: Table A.1, Suter & Tsao (1996)

APPENDIX D

Detailed Summary of Benthic Invertebrate Abundance and Relative Tolerance Rankings by Station

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PRICKLY PEAR CREEK

Order	Taxa	Species	Feeding Group[1]	Species Tolerance Ranking[2]			Station Relative Abundance Ranking[3]					Comments
				RBP HBI	MT HBI	MT Metals	PPC-1	PPC-2	PPC-3	PPC-4	PPC-5	
Ephemeroptera	Leptohyphidae	Tricoythodes sp.	CG	5	4	4	0	0	0	0	2	
Ephemeroptera	Ephermerellidae	Caudatella sp.	GC	1	0	--	1	0	0	0	0	
~~Ephemeroptera~~	~~Ephermerellidae~~	~~Drunella sp. (I)~~	~~SC, PR~~	~~0~~	~~0~~	~~0~~	~~2~~	~~1~~	~~1~~	~~0~~	~~0~~	
Ephemeroptera	Ephermerellidae	Drunella sp. (II)	SC, PR	0	0	0	1	0	0	0	0	*D. spinifera*
Ephemeroptera	Ephermerellidae	Ephemerella sp.	GC	1	1.5	--	2	0	0	0	1	
Ephemeroptera	Leptophlebiidae	Paraleptophlebia sp.	GC	1	1	1	1	1	0	0	1	
Ephemeroptera	Baetidae	Baetis sp.	GC, SC	5	5	4	1	1	2	2	0	
Ephemeroptera	Heptageniidae	Stenonema sp.	SC	2	3.5	--	1	0	0	0	1	
Plecoptera	Pteronarcyidae	Pteronarcella badia	SH	0	3	4	0	1	1	1	1	
Plecoptera	Pteronarcyidae	Pteronarcys californica	SH	0	2	1	1	2	2	1	0	
Plecoptera	Nemouridae	Malenka sp.	SH	2	1	1	1	0	0	0	0	
Plecoptera	Nemouridae	Zapada cinctipes	SH	2	3	3	2	0	1	0	0	
Plecoptera	Nemouridae	Zapada sp.	SH	2	2	--	1	0	0	0	0	
Plecoptera	Perlidae	Claassenia sabulosa	PR	3	3	3	0	2	2	1	0	
Plecoptera	Perlidae	Hesperoperla pacifica	PR	1	1	3	1	2	1	0	0	
Plecoptera	Perlidae	Doroneuris theodora	PR	1	0	2	2	0	0	0	0	
Plecoptera	Chloroperlidae	Sweltsa sp.	PR	1	0	--	1	0	0	0	0	
Plecoptera	Perlodidae	Megarcys sp.	PR	2	1	1	1	0	0	0	0	
Plecoptera	Perlodidae	Skwala sp.	PR	2	3	3	0	0	2	0	3	
Tricoptera	Helicopsychidae	Helicopsyche borealis	SC	3	3	3	0	3	2	1	2	
Tricoptera	Hydropsychidae	Arctopsyche sp.	FC	1	2	3	2	1	0	0	0	
Tricoptera	Hydropsychidae	Hydropsyche sp.	FC	4	5	5	1	3	4	4	2	
Tricoptera	Hydropsychidae	Cheumatopsyche sp.	FC	5	5	5	0	0	0	0	1	
Tricoptera	Leptoceridae	Oecetis sp.	PR	8	8	3	0	1	1	1	2	
Tricoptera	Lepidostomatidae	Lepidostoma sp.	SH	1	1	1	0	0	0	0	1	
Tricoptera	Rhyacophilidae	Rhyacophila brunnea (I)	PR	1	0	1	2	0	1	0	0	
Tricoptera	Rhyacophilidae	Rhyacophila sp. (II)	PR	0	1	--	1	1	1	1	0	*R. rotunda*
Tricoptera	Rhyacophilidae	Rhyacophila sp. (III)	PR	0	1	--	1	0	1	0	0	*R. narvae*
Tricoptera	Philopotamidae	Dolophilodes sp.	GC	1	0	1	3	0	0	0	0	
Tricoptera	Brachycentridae	Brachycentrus sp. (I)	FC, SC	1	1	4	2	0	3	0	0	*B. americanus*
Tricoptera	Brachycentridae	Brachycentrus sp. (II)	FC, SC	1	2	3	0	2	0	0	0	*B. occidentalis*
Tricoptera	Brachycentridae	Brachycentrus sp. (III)	FC, SC	1	1	--	0	1	0	0	0	species unknown
Tricoptera	Brachycentridae	Micrasema sp.	SH, GC	1	1	2	2	0	0	2	0	
Tricoptera	Glossosomatidae	Glossosoma sp.	SC	0	0	2	1	0	2	0	2	
Odonata	Gomphidae	Ophiogomphus sp.	PR	1	5	4	0	0	0	1	0	
Hemiptera	Corixidae	Sigara sp.	GC	9	5	3	1	0	0	0	2	ID uncertain
Hemiptera	Gerridae	Trepobates sp.	PR	10	--	--	0	0	0	0	1	
Coleoptera	Dytiscidae	unknown	PR	5	7	5	0	1	0	0	1	
Coleoptera	Elmidae	Lara sp. (L)	SH	4	1	1	1	0	0	0	0	
Coleoptera	Elmidae	Stenelmis occidentalis (A)	SC, OM	7	5	3	1	0	1	0	0	
Coleoptera	Elmidae	Cleptelmis ornata (L)	GC	4	4	4	2	1	0	0	0	
Coleoptera	Elmidae	Cleptelmis ornata (A)	GC	4	4	4	1	0	0	0	1	
Coleoptera	Elmidae	Optioservus quadrimaculatus (L)	SC	4	5	5	2	2	2	1	2	
Coleoptera	Elmidae	Optioservus quadrimaculatus (A)	SC	4	5	5	3	2	1	0	2	
Coleoptera	Elmidae	Zaitzevia parvula (L)	GC	4	4	3	0	2	2	2	2	
Coleoptera	Elmidae	Zaitzevia parvula (A)	GC	4	4	3	1	3	2	2	2	
Coleoptera	Elmidae	Heterlimnius corpulentus (L)	GC	4	3	3	3	0	0	0	0	
Coleoptera	Elmidae	Heterlimnius corpulentus (A)	GC	4	3	3	1	0	0	0	0	
Coleoptera	Chrysomelidae	Donacia sp.	SH	--	--	--	0	0	1	0	0	

PRICKLY PEAR CREEK

Order	Taxa	Species	Feeding Group[1]	Species Tolerance Ranking[2] RBP HBI	MT HBI	MT Metals	Station Relative Abundance Ranking[3] PPC-1	PPC-2	PPC-3	PPC-4	PPC-5	Comments
Diptera	Tipulidae	Tipula sp.	SH	4	4	4	0	0	0	1	3	
Diptera	Tipulidae	Antocha sp.	GC	3	3	4	3	1	1	0	0	
Diptera	Tipulidae	Dicranota sp.	PR	3	3	2	1	0	0	0	0	
Diptera	Tipulidae	Hexatoma sp.	PR	2	2	2	0	3	2	3	1	
Diptera	Simuliidae	Prosimulium sp.	FC	3	4	2	0	1	0	0	0	
Diptera	Simuliidae	Simulium sp.	FC	6	5	5	1	1	1	1	0	
Diptera	Simuliidae	Simulium sp. (P)	FC	6	5	5	0	1	1	1	0	
Diptera	Ceratopogonidae	Probezzia sp.	PR	6	6	5	1	0	0	0	0	
Diptera	Chironomidae	unknown	PR, GC	6	10	--	0	0	1	1	1	
Diptera	Chironomidae	Nostococladius sp.	SH	7	10	--	1	0	0	0	0	
Diptera	Psychodidae	Pericoma sp.	GC	4	4	4	1	0	0	0	0	
Diptera	Ahericidae	Atherix sp.	PR	2	5	5	0	0	2	2	0	
Diptera	Pelecorhynchidae	Glutops sp.	PR	3	--	--	1	0	1	0	0	
Diptera	Dolichopodidae	Dolichopus sp.	PR	4	4	4	1	0	0	0	0	
Diptera	Muscidae	Lispoides sp.	PR	6	6	7	0	0	0	0	3	
Gastropoda	Lymnaeidae	unknown	SC	6	6	3	0	0	1	0	0	
Gastropoda	Physidae	Physella sp.	SC	8	8	4	1	3	1	3	2	
Gastropoda	Ancylidae	Ferrissia rivularis	SC	6	6	1	0	1	0	0	0	
Gastropoda	Planorbidae	unknown	SC	7	6	3	0	1	0	0	0	
Gastropoda	Plelcypoda	Pisidium sp.	FC	8	8	3	0	0	0	1	1	
Amphipoda	Talitridae	Hyalella azteca	GC	8	8	3	1	0	0	0	0	
Oligochaeta	unknown	unknown	GC	5	10	--	2	0	0	0	0	
Acari	unknown	unknown	PR	--	5	5	1	0	0	0	0	

(P) = pupal life stage	46	28	31	21	26	# species total
(L) = larval life stage	24	14	16	9	12	# EPT species
(A) = adult life stage	65	45	47	33	43	relative abundance

RBP HBI = Rapid Bioassessment Protocol, Hilsenhoff Biotic Index - indicates degree of tolerance towards organic pollution
MT HBI = Montana-specific, Hilsenhoff Biotic Index (Bukantis, 1998) - indicates degree of tolerance towards organic pollution
MT Metals = Montana-specific, Metals Index (Bukantis, 1998) - indicates degree of tolerance towards metals pollution

[1] Functional Feeding Groups:
GC = gatherer/collector
SC = scraper
SH = shredder
F = filterer
PR = predator
OM = omnivore
PC = piercer

[2] Relative Tolerance Ranking:
0 = intolerant
>>>>
10 = tolerant

[3] Relative Abundance Ranking:
0 = absent
1 = rare
2 = common
3 = abundant
4 = dominant

UPPER LAKE AND MARSH AREA

Order	Taxa	Species	Feeding Group[1]	Tolerance Ranking[2] RBP HBI	MT HBI	MT Metals	Relative Abundance Ranking[3] Upper Lake	Marsh Area	Canyon Ferry	Comments
Oligochaeta	unknown	unknown	GC	5	10	--	1	0	1	
Hirundinea	unknown	unknown	PR	--	8	--	1	0	0	
Acari	unknown	unknown	PR	--	5	5	0	0	1	
Cladocera	Daphnia	unknown	FC	8	--	--	2	0	0	
Decapoda	unknown	unknown	SH, OM	8	6	3	1	0	0	
Amphipoda	Talitridae	Hyalella azteca	GC	8	8	3	3	2	0	
Amphipoda	Talitridae	Gammarus sp.	OM	8	4	1	2	0	0	
Epemeroptera	Caenidae	Caenis sp.	GC	7	7	3	0	0	1	
Epemeroptera	Siphlonuridae	Siphlonorus sp.	GC	7	2	1	2	1	0	
Tricoptera	Hydroptilidae	Agraylea sp.	PI, GC	8	8	2	1	0	0	
Tricoptera	Leptoceridae	Oecetis sp.	PR	8	8	3	0	0	1	
Odonata	Coenagrionidae	Enallagma sp.	PR	9	7	3	2	0	0	
Odonata	Aeshnidae	Boyeria sp.	PR	--	--	--	2	0	0	
Odonata	Aeshnidae	Aeshna sp.	PR	5	--	--	1	1	0	
Hemiptera	Corixidae	Sigara sp.	GC	9	5	3	3	2	3	ID uncertain
Hemiptera	Notonectidae	Notonecta sp.	PR	--	5	3	3	0	0	
Coleoptera	Dytiscidae	unknown	PR	5	5	7	1	0	0	
Coleoptera	Haliplidae	Haliplus sp. (L)	PI, SH	--	--	--	1	0	0	
Coleoptera	Haliplidae	Haliplus sp. (A)	PI, SH	--	--	--	3	0	0	
Diptera	Tipulidae	Tipula sp.	SH	4	4	4	0	0	1	
Diptera	Chironomidae	unknown	PR, GC	6	10	--	2	1	1	
Gastropoda	Physidae	Physella sp.	SC	8	8	4	3	1	0	
Gastropoda	Planorbidae	unknown	SC	7	6	3	3	0	0	
Gastropoda	Ancylidae	Ferrissia rivularus	SC	6	6	1	0	0	1	

	Upper Lake	Marsh Area	Canyon Ferry	
(L) = larval life stage	19	6	8	# species total
(A) = adult life stage	2	1	2	# EPT species
	37	8	10	relative abundance

RBP HBI = Rapid Bioassessment Protocol, Hilsenhoff Biotic Index - indicates degree of tolerance towards organic pollution
MT HBI = Montana-specific, Hilsenhoff Biotic Index (Bukantis, 1998) - indicates degree of tolerance towards organic pollution
MT Metals = Montana-specific, Metals Index (Bukantis, 1998) - indicates degree of tolerance towards metals pollution

[1] Functional Feeding Groups:
GC = gatherer/collector
SC = scraper
SH = shredder
F = filterer
PR = predator
OM = omnivore
PC = piercer

[2] Relative Tolerance Ranking:
0 = intolerant
>>>>
10 = tolerant

[3] Relative Abundance Ranking:
0 = absent
1 = rare
2 = common
3 = abundant
4 = dominant

APPENDIX E

Wildlife Exposure Factors

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Mallard

Anas platyrhynchos

Parameter	Symbol	Reported Values	Reference	Values Identified for SLERA
Body Weight	BW	1.225 Mean (kg) - adult males, North America 1.043 Mean (kg) - adult females, North America 1.246 Mean (kg) - adult males in winter, Mississippi 1.095 Mean (kg) - adult females in winter, Mississippi 1.237 Mean (kg) - adult males in winter, Texas 1.088 Mean (kg) - adult females in winter, Texas 1.197 Mean (kg) - adult females in spring, North Dakota	USEPA, 1993	Average of reported means: **1.162** **kg ww**
Food Ingestion Rate	IR_{food}	No measured values available; estimated from avian allometric equation for food ingestion provided in USEPA (1993). Assumes 18% dry matter in food (CF = 0.18 kg food dw / kg food ww).	USEPA, 1993	Estimated from allometric equation: IR_{food} *(kg dw/day) =* $[0.0582 * BW\ (kg\ ww)^{0.651}] / CF$ *(dw/ww)* **0.356** **kg ww/day**
Water Ingestion Rate	IR_{water}	No measured values available; estimated from avian allometric equation for water ingestion provided in USEPA (1993).	USEPA, 1993	Estimated from allometric equation: $IR\ (L/day) = 0.059 * BW\ (kg\ ww)^{0.67}$ **0.065** **L/day**
Sediment Ingestion Rate	IR^{sed}	No measured values available; estimated fraction of sediment in the diet is 0.06 (6%). Assumes 18% dry matter in food (CF = 0.18 kg food dw / kg food ww).	Beyer et al., 1998	Based on fraction of sediment/soil in the diet: $IR_{soil/sed} = IR_{food}$ *(kg ww/day) * % in diet * CF (dw/ww)* **0.0038** **kg dw/day**
Dietary Composition (fraction wet volume)	DF	North Dakota, prairie potholes 75% total invertebrates: average in spring 25% total plants: average in spring	USEPA, 1993	**DFaquatic invert = 75%** **DFaquatic plant = 25%**
Home Range Size	HR	468 Mean (ha) - adult females, total - North Dakota, prairie potholes 111 Mean (ha) - adult females, laying - North Dakota, prairie potholes	USEPA, 1993	Average of reported means: **111** **hectares**
Seasonal Area Use Factor	AUF	Migratory in northern portion of range. Leave breeding grounds from September to November returning in spring.	USEPA, 1993	

References:

USEPA. 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. December 1993. EPA/600/R-93/187a,b

Beyer, W.N, D.J. Audet, A. Morton, J.K. Campbell, and L. LeCaptain. 1998. Lead Exposure of Waterfowl Ingesting Coeur d'Alene River Basin Sediments. J Environ Qual (27):1533-1538.

Belted Kingfisher *Ceryle alcyon*				
Parameter	**Symbol**	**Reported Values**	**References**	**Values Identified for ERA**
Habitat		Forages on ground in open areas along habitat edges of streams, rivers ponds and lakes where fish concentrations are greatest. Nests in burrows that are devoid of vegetation.	USEPA, 1993	
Body Weight (kg wet weight)	BW	0.148 - Mean - adults - Pennsylvani 0.136 - Mean - adults - Pennsylvani 0.158 - Mean - adults - Ohio	USEPA, 1993	Mean of reported means: 0.147
Food Ingestion Rate (kg wet weight/day)	IR_{food}	0.5 g/g-day - Mean - adults - northcentral lower Michigan	USEPA, 1993	Mean value: 0.07
Water Ingestion Rate (L/day)	IR_{water}	Specific values not available. Estimated based on following equation $IR_{water} = 0.059*BW^{0.67}$	USEPA, 1993	Estimated from equation: 0.016
Sediment Ingestion Rate (kg dry weight/day)	IR_{sed}	Ingestion of sediment (I_{sed}) or soil (I_{soil}) as percentage of food intake (kg dry weight/kg food dry weight) is not available. Assumed to be equal to 1%.	Assumption	IR_{sed} (or IR_{soil}) = IRfood*0.27*$I_{sed/soil}$ Where 0.27 (kg food dry weight /kg food wet weight) = wet weight to dry weight conversion factor for food assuming 27% dry matter in food: 0.0002
Dietary Composition (fraction wet volume)	df	Michigan/trout streams Game fish: 43% Forage fish: 15% Unidentified fish: 1% Invertebrates: 41%	USEPA, 1993	Fraction fish = df_{fish} =1
Home Range Size	HR	During the spring and early summer the breeding pairs defend both the territory including both their nest site and their foraging area. By autumn each bird defends an individual feeding territory only. Breeding territori can be more than twice as long as the feeding territory. Foraging territor is inversely related to prey abundance.	USEPA, 1993	No Info
Foraging Distance (km)		Foraging distance in early summer (breeding pairs 2.19 - Mean - Pennsylvani 1.03 - Mean - Ohio/streams 1.03 - Mean - southwest Ohio/streams	USEPA, 1993	Mean of means for breeding pairs 1.42
Seasonal Use		Migratory in northern portion of range. Leave breeding grounds from October to December returning from February to April.	USEPA, 1993	

Cliff Swallow *Petrochelidon pyrchonota*				
Parameter	**Symbol**	**Reported Values**	**Reference**	**Values Identified for SLERA**
Body Weight	BW	21.6 Mean (g) - adult males & females, California 23.9 Mean (g) - adult male during nesting, Nebraska 24.15 Mean (g) - adult female during nesting, Nebraska	Sample et al., 1997	Average of reported means: **0.023** **kg ww**
Food Ingestion Rate	IR_{food}	No measured values available; estimated from avian allometric equation for food ingestion provided in USEPA (1993). Assumes 40% dry matter in food (CF = 0.40 kg food dw / kg food ww).	USEPA, 1993	Estimated from allometric equation: IR_{food} *(kg dw/day) = [0.0582*BW (kg ww)*$^{0.651}$*] / CF (dw/ww)* **0.013** **kg ww/day**
Water Ingestion Rate	IR_{water}	No measured values available; estimated from avian allometric equation for water ingestion provided in USEPA (1993).	USEPA, 1993	Estimated from allometric equation: *IR (L/day) = 0.059 * BW (kg ww)*$^{0.67}$ **0.0047** **L/day**
Sediment Ingestion Rate	IR_{sed}	No measured values available; estimated fraction of sediment in the diet is assumed to be 0.07 (7%) based on professional judgement. Assumption based on burrowing behavior in the banks of rivers or streams while constructing nes and intentional ingestion of grit to aid in digestion. Assumes 40% dry matter in food (CF = 0.40 kg food dw / kg food ww).	Assumption Sample et al., 1997	Based on fraction of sediment in the diet: IR_{sed} = IR_{food} *(kg ww/day) * sediment in diet * CF (dw/ww)* **0.0004** **kg dw/day**
Dietary Composition (fraction wet volume)	DF	Diet consists entirely of invertebrates, including emerging aquatic invertebrate flying insects, beetles, grasshoppers, dragonflies, spiders, etc.	Sample et al., 1997	**DFaerial inverts = 100%** ***(represented by emerging aquatic invertebrates)***
Home Range Size	HR	Most foraging will occur within a 1.5km to 6km radius around the population colony.	Sample et al., 1997	no info
Seasonal Area Use Factor	AUF	Migatory, winters in southern US, Mexico and South America.	Sample et al., 1997	

References:

Sample, B.E., M.S. Aplin, R.A. Efroymson, G.W. Suter II, C.J.E. Welsh. 1997. Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants. Oak Ridge National Laboratory. October 1997. ORNL/TM-13391.

USEPA. 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. December 1993. EPA/600/R-93/187a,b

Mink *Mustela vison*				
Parameter	**Symbol**	**Reported Values**	**References**	**Values Identified for ERA**
Body Weight	BW	1.040 Mean (kg) - adult male - summer - Montana 1.233 Mean (kg) - adult male - fall - Montana 0.550 Mean (kg) - adult female- summer - Montana 0.586 Mean (kg) - adult female - fall - Montana 0.777 Mean (kg) - juvenile male - summer - Montana 0.533 Mean (kg) - juvenile female - summer - Montana	USEPA, 1993	Average of reported means for females: **0.556** **kg ww**
Food Ingestion Rate	IR_{food}	0.13 Mean (g/g BW/day) - captive males 0.12 Mean (g/g BW/day) - farm raised males 0.16 Mean (g/g BW/day) - farm raised females	USEPA, 1993	Reported mean for females (adj by BW): *IR (kg ww/day) = IR (g ww/g BW-day) * BW (kg)* **0.089** **kg ww/day**
Water Ingestion Rate	IR_{water}	0.099 Mean (g/g BW/day) - farm raised males 0.028 Mean (g/g BW/day) - farm raised females *(Water density = 1 g/mL)*	USEPA, 1993	Reported mean for females (adj by BW): *IR (L/day) = IR (g/g BW-day) * BW (kg)* **0.016** **L/day**
Sediment Ingestion Rate	IR_{sed}	No measured values available; estimated fraction of sediment in the diet is assumed to be 0.01 (1%) based on professional judgement. Assumes 25% dry matter in food (CF = 0.25 kg food dw / kg food ww).	Assumption	Based on fraction of sediment in the diet: $IR_{sed} = IR_{food}$ *(kg ww/day) * soil in diet * CF (dw/ww)* **0.00022** **kg dw/day**
Dietary Composition (fraction wet volume)	DF	Mink are opportunistic feeders taking whatever prey is abundant. In many parts of its range mammals are the most important prey but mink hunt aquatic prey as well depending on the season. In mink intestines collected from a Montana river, percent freqency of occurren in samples for food items: 61.5% fish; 19.2% mammals and 26.9% aquatic invertebrates. In mink stomachs the frequency of occurrence was: 11.5% fish, and 7.2% mammals.	USEPA, 1993 RCG, Hagler Bailly, 1995	**DFfish = 100%**
Home Range Size	HR	Range size and shape depends on habitat. Shape is linear along streams and circular in marshes. Montana /riverine environment: 7.8 Mean (ha) Female mink in heavy vegetation 20.4 Mean (ha) Female mink in sparse vegetation	USEPA, 1993	Average of reported values: **14.1** **ha**
Seasonal Area Use Factor	AUF	Mink are nocturnal and active year round.	USEPA, 1993	

References:

USEPA. 1993. Wildlife Exposure Factors Handbook. Office of Research and Development. December 1993. EPA/600/R-93/187a,b

RCG, Hagler Bailly. 1995.

APPENDIX F

Detailed Hazard Quotients for Each Exposure Pathway for Each Representative Wildlife Species

Waterfowl: Mallard Duck
Piscivorous Bird: Belted Kingfisher
Insectivorous Bird: Cliff Swallow
Piscivorous Mammal: Mink

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APPENDIX F
Estimated Risks to the Mallard Duck from Ingestion of Contaminated Media

Location	Analyte	Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Lower Lake	Antimony	--	--	--	--	--	No TRV
	Arsenic	<1	**1.9**	--	--	--	**1.9**
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	**6.2**	--	--	--	**6.2**
	Chromium	<1	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	**3.8**	--	--	--	**3.8**
	Lead	<1	**29**	--	--	--	**29**
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	<1	--	--	--	<1
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	**6.3**	--	--	--	**6.4**
	Silver	--	--	--	--	--	No TRV
	Thallium	--	--	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	**1.4**	--	--	--	**1.4**
Upper Lake/Marsh Area	Antimony	ND	--	--	--	--	No TRV
	Arsenic	<1	<1	ND	ND	<1	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	<1	--	**1.4**	<1	**2.4**
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	**3.4**	--	**7.3**	<1	**11**
	Lead	<1	**21**	--	**14**	**2.1**	**37**
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	<1	--	--	--	<1
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	<1	ND	ND	ND	<1
	Silver	--	--	--	--	--	No TRV
	Thallium	ND	--	--	--	--	No TRV
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	**1.3**	--	<1	<1	**2.5**
Canyon Ferry Reservoir	Antimony	--	ND	--	--	--	No TRV
	Arsenic	<1	<1	ND	ND	ND	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	--	--	--	--	--	No TRV
	Cadmium	<1	<1	ND	<1	<1	<1
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	<1	--	<1	<1	**1.1**
	Lead	<1	<1	ND	<1	<1	1
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	ND	--	--	--	NC
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	ND	ND	ND	ND	<1
	Silver	--	ND	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	No TRV
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	<1	--	<1	<1	<1

APPENDIX F

Estimated Risks to the Mallard Duck from Ingestion of Contaminated Media

Location	Analyte	**Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs**					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Prickly Pear Creek	Antimony	ND	--	--	--	--	No TRV
	Arsenic	<1	<1	--	<1	<1	1.2
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	<1	--	<1	<1	<1
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	--	3.5	1.2	5.4
	Lead	<1	2.3	--	2.8	<1	6.1
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	<1	--	--	--	<1
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	<1	--	--	--	<1
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	--	1.6	<1	2.9
Prickly Pear Creek (upstream)	Antimony	--	--	--	--	--	No TRV
	Arsenic	ND	<1	--	<1	<1	<1
	Barium	ND	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	ND	<1	--	<1	<1	<1
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	--	2.5	<1	3.4
	Lead	ND	<1	--	2.2	<1	3.1
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	--	ND	--	--	NC
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	--	--	--	--	NC
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	--	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	--	1.1	<1	1.6

-- = exposure pathway incomplete, or data (either toxicity or exposure data) are not available to calculate an HQ.

NC = Not Calculated

ND = Not Detected

HQ values greater than 1 are shaded and presented to two significant figures.

APPENDIX F
Estimated Risks to the Belted Kingfisher from Ingestion of Contaminated Media

Location	Analyte	Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Lower Lake	Antimony	--	--	--	--	--	No TRV
	Arsenic	<1	<1	--	--	--	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	**2.5**	--	--	--	**2.5**
	Chromium	<1	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	**1.5**	--	--	--	**1.5**
	Lead	<1	**12**	--	--	--	**12**
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	<1	--	--	--	<1
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	**2.5**	--	--	--	**2.5**
	Silver	--	--	--	--	--	No TRV
	Thallium	--	--	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	--	--	--	<1
Upper Lake/Marsh Area	Antimony	ND	--	--	--	--	No TRV
	Arsenic	<1	<1	ND	ND	--	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	<1	<1	--	--	<1
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	**1.3**	**2**	--	--	**3.3**
	Lead	<1	**8.2**	**7.6**	--	--	**16**
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	<1	**1.4**	--	--	**1.6**
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	<1	ND	ND	ND	<1
	Silver	--	--	--	--	--	No TRV
	Thallium	ND	--	--	--	--	No TRV
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	<1	**1.9**	--	--	**2.4**
Canyon Ferry Reservoir	Antimony	--	ND	--	--	--	No TRV
	Arsenic	<1	<1	ND	ND	ND	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	--	--	--	--	--	No TRV
	Cadmium	<1	<1	ND	--	--	<1
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	<1	<1	--	--	<1
	Lead	<1	<1	ND	--	--	<1
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	ND	<1	--	--	<1
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	ND	ND	ND	ND	<1
	Silver	--	ND	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	No TRV
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	<1	1	--	--	1

APPENDIX F
Estimated Risks to the Belted Kingfisher from Ingestion of Contaminated Media

Location	Analyte	Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Prickly Pear Creek	Antimony	ND	--	--	--	--	No TRV
	Arsenic	<1	<1	<1	--	--	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	<1	<1	--	--	<1
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	**1.4**	--	--	**1.7**
	Lead	<1	<1	**1.9**	--	--	**2.9**
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	<1	<1	--	--	<1
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	<1	--	--	--	<1
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	**1.6**	--	--	**1.9**
Prickly Pear Creek (upstream)	Antimony	--	--	--	--	--	No TRV
	Arsenic	ND	<1	<1	--	--	<1
	Barium	ND	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	ND	<1	<1	--	--	<1
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	**1.6**	--	--	**1.7**
	Lead	ND	<1	1	--	--	**1.1**
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	--	ND	--	--	NC
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	--	--	--	--	NC
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	--	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	**1.6**	--	--	**1.7**

-- = exposure pathway incomplete, or data (either toxicity or exposure data) are not available to calculate an HQ.

NC = Not Calculated

ND = Not Detected

HQ values greater than 1 are shaded and presented to two significant figures.

APPENDIX F
Estimated Risks to the Cliff Swallow from Ingestion of Contaminated Media

Location	Analyte	Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Lower Lake	Antimony	--	--	--	--	--	No TRV
	Arsenic	<1	8.3	--	--	--	8.3
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	28	--	--	--	28
	Chromium	<1	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	17	--	--	--	17
	Lead	<1	130	--	--	--	130
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	1.8	--	--	--	1.8
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	28	--	--	--	28
	Silver	--	--	--	--	--	No TRV
	Thallium	--	--	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	6.1	--	--	--	6.1
Upper Lake/Marsh Area	Antimony	ND	--	--	--	--	No TRV
	Arsenic	<1	1.6	ND	ND	--	1.6
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	3.5	--	3.7	--	7.2
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	15	--	19	--	34
	Lead	<1	93	--	37	--	130
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	2	--	--	--	2
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	1.3	ND	ND	ND	1.3
	Silver	--	--	--	--	--	No TRV
	Thallium	ND	--	--	--	--	No TRV
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	5.8	--	2.1	--	7.9
Canyon Ferry Reservoir	Antimony	--	ND	--	--	--	No TRV
	Arsenic	<1	<1	ND	ND	ND	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	--	--	--	--	--	No TRV
	Cadmium	<1	<1	ND	<1	--	<1
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	<1	--	2.4	--	2.6
	Lead	<1	<1	ND	1.4	--	1.6
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	ND	--	--	--	NC
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	ND	ND	ND	ND	<1
	Silver	--	ND	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	No TRV
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	<1	--	<1	--	<1

APPENDIX F
Estimated Risks to the Cliff Swallow from Ingestion of Contaminated Media

Location	Analyte	Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Prickly Pear Creek	Antimony	ND	--	--	--	--	No TRV
	Arsenic	<1	<1	--	<1	--	**1.3**
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	<1	<1	--	**1.5**	--	**1.9**
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	**3.2**	--	**9.2**	--	**12**
	Lead	<1	**10**	--	**7.3**	--	**18**
	Manganese	<1	**1.8**	--	--	--	**1.8**
	Mercury	ND	<1	--	--	--	<1
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	<1	--	--	--	<1
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	**3.4**	--	**4.1**	--	**7.5**
Prickly Pear Creek (upstream)	Antimony	--	--	--	--	--	No TRV
	Arsenic	ND	<1	--	<1	--	<1
	Barium	ND	<1	--	--	--	<1
	Beryllium	ND	--	--	--	--	No TRV
	Cadmium	ND	<1	--	<1	--	<1
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	--	**6.4**	--	**6.7**
	Lead	ND	<1	--	**5.6**	--	**6.6**
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	--	ND	--	--	NC
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	--	--	--	--	NC
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	--	--	--	--	No TRV
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	--	**2.9**	--	**3.3**

-- = exposure pathway incomplete, or data (either toxicity or exposure data) are not available to calculate an HQ.

NC = Not Calculated

ND = Not Detected

HQ values greater than 1 are shaded and presented to two significant figures.

APPENDIX F
Estimated Risks to the Mink from Ingestion of Contaminated Media

Location	Analyte	Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Lower Lake	Antimony	<1	6.8	--	--	--	7.6
	Arsenic	<1	3.8	--	--	--	3.8
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	<1	--	--	--	<1
	Cadmium	<1	1.4	--	--	--	1.4
	Chromium	<1	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	--	--	--	<1
	Lead	<1	1.2	--	--	--	1.2
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	<1	--	--	--	<1
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	3.4	--	--	--	3.6
	Silver	--	--	--	--	--	No TRV
	Thallium	<1	1.7	--	--	--	1.7
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	--	--	--	<1
Upper Lake/Marsh Area	Antimony	ND	<1	--	--	--	<1
	Arsenic	<1	<1	ND	ND	--	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	<1	--	--	--	<1
	Cadmium	<1	<1	<1	--	--	<1
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	<1	<1	--	--	<1
	Lead	<1	<1	<1	--	--	1.7
	Manganese	<1	<1	--	--	--	<1
	Mercury	<1	<1	<1	--	--	<1
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	<1	ND	ND	ND	<1
	Silver	--	--	--	--	--	No TRV
	Thallium	ND	<1	--	--	--	<1
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	<1	1.1	--	--	1.4
Canyon Ferry Reservoir	Antimony	<1	ND	--	--	--	<1
	Arsenic	<1	<1	ND	ND	ND	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	<1	<1	--	--	--	<1
	Cadmium	<1	<1	ND	--	--	<1
	Chromium	<1	<1	--	--	--	<1
	Cobalt	<1	<1	--	--	--	<1
	Copper	<1	<1	<1	--	--	<1
	Lead	<1	<1	ND	--	--	<1
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	ND	<1	--	--	<1
	Nickel	<1	<1	--	--	--	<1
	Selenium	<1	ND	ND	ND	ND	<1
	Silver	--	ND	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	NC
	Vanadium	<1	<1	--	--	--	<1
	Zinc	<1	<1	<1	--	--	<1

APPENDIX F
Estimated Risks to the Mink from Ingestion of Contaminated Media

Location	Analyte	Summary of Exposure Pathway HQs and Total HQs Based on NOAEL TRVs					
		Surface Water HQ	Sediment HQ	Fish HQ	Aquatic Invert. HQ	Aquatic Plants HQ	**Total HQ = ∑ HQs**
Prickly Pear Creek	Antimony	ND	<1	--	--	--	<1
	Arsenic	<1	<1	<1	--	--	<1
	Barium	<1	<1	--	--	--	<1
	Beryllium	ND	<1	--	--	--	<1
	Cadmium	<1	<1	<1	--	--	<1
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	<1	--	--	<1
	Lead	<1	<1	<1	--	--	<1
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	<1	<1	--	--	<1
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	<1	--	--	--	<1
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	ND	--	--	--	NC
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	<1	--	--	**1.1**
Prickly Pear Creek (upstream)	Antimony	<1	--	--	--	--	<1
	Arsenic	ND	<1	<1	--	--	<1
	Barium	ND	<1	--	--	--	<1
	Beryllium	ND	<1	--	--	--	<1
	Cadmium	ND	<1	<1	--	--	<1
	Chromium	ND	<1	--	--	--	<1
	Cobalt	ND	<1	--	--	--	<1
	Copper	<1	<1	<1	--	--	<1
	Lead	ND	<1	<1	--	--	<1
	Manganese	<1	<1	--	--	--	<1
	Mercury	ND	--	ND	--	--	NC
	Nickel	ND	<1	--	--	--	<1
	Selenium	ND	--	--	--	--	NC
	Silver	ND	--	--	--	--	No TRV
	Thallium	ND	--	--	--	--	NC
	Vanadium	ND	<1	--	--	--	<1
	Zinc	<1	<1	<1	--	--	<1

-- = exposure pathway incomplete, or data (either toxicity or exposure data) are not available to calculate an HQ.

NC = Not Calculated

ND = Not Detected

HQ values greater than 1 are shaded and presented to two significant figures.